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PHYSICS SESSIONAL
FOR UNDERGRADUATE STUDENTS

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MECHANICS

Experiment 1

Determination of Instrumental Errors and Measurement of Length, Mass and Time of a given object

Measurement of length is necessary in almost all experiments in physics. Where great accuracy is not required a meter rod can be used conveniently to measure the distances correct up to a millimeter. To measure a length, correct up to a fraction of a millimeter the divisions must be further subdivided. It is not practicable beyond a certain limit because it is difficult to see the small divisions clearly. Moreover, closer the division on the scale, the greater is the inaccuracy in graduation. Hence for measurements accurate up to 1/10th or 1/100th of a millimeter the various devices are.

1. Slide calipers
2. Screw gauge and
3. Spherometer

1. Slide Calipers

A slide calipers (Figure 1) consists of a nickel plate steel scale usually graduated in inches on the other edge. This is known as the main scale. Over this scale slides a small scale called the Vernier scale.

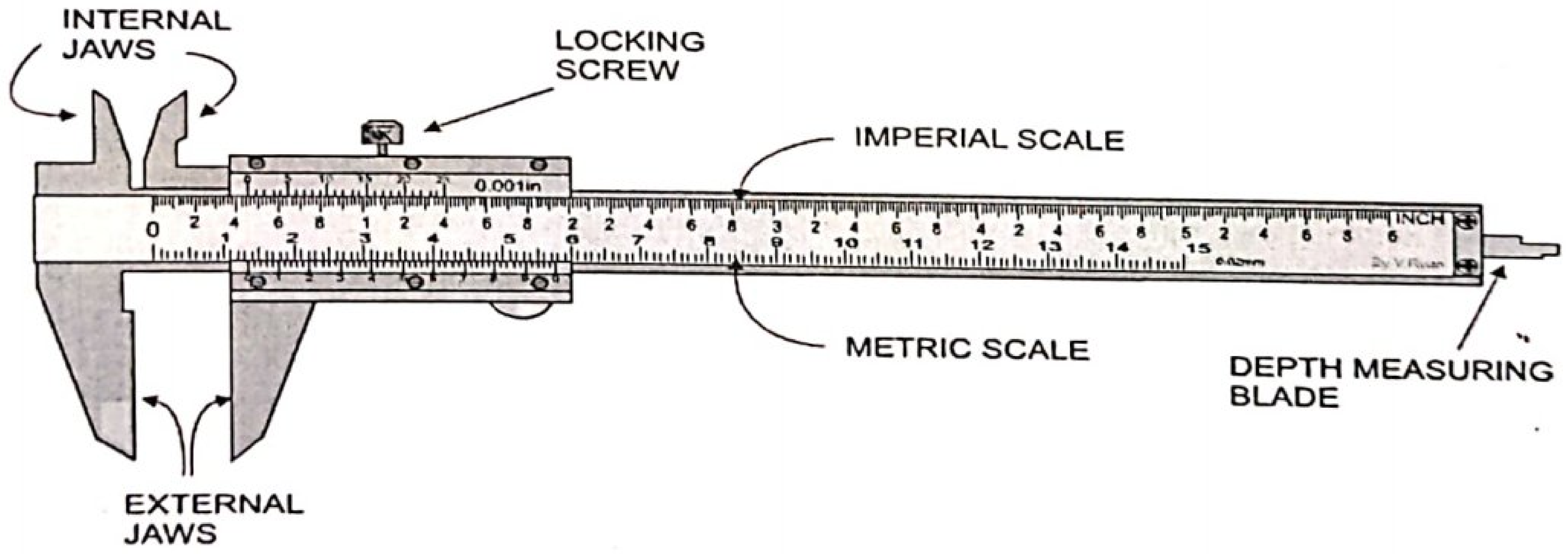


Figure 1: Slide Calipers

i) Instrumental Error:

When the Vernier zero does not coincide with the main scale zero, there is an instrumental error of zero error. There may be two types of zero errors:

1. The zero of the Vernier may be in advance of the zero line of the main scale by an amount x mm. This means that in place of zero reading the instrument is giving a reading + x mm. On placing the body between the jaws if the scale reading be y mm them then the actual reading of the body is (y-x) mm. In this case the instrumental error is + ve and must always are subtracted.
2. When Vernier zero is behind that of the main scale by an amount x mm, the instrumental error is –ve and must be added to the actual reading to get true length of the body.

ii) Vernier Constant:

Vernier constant is a measure of the difference in length of a scale division and a Vernier division in the unit of the scale division.

Let these 10 Vernier divisions coincide with 9 main scale divisions. Since 10 divisions of the Vernier scale coincide with 9 main scale divisions

$$1 \quad \text{V. D.} = \frac{9}{10}\text{S.D.}$$

$$\text{VC} = 1 \text{ S. D.} - 1\text{V. D.} = \left(1-\frac{9}{10}\right)\text{ S. D.} = \frac{1}{10}\text{ S. D.} = 0.1 \text{ S.D.}$$[Corrected form D.S.D=Difference of Scale Division]

Let the value of one small division of the main scale =1 mm.

Vernier constant (V. C.) = 0.1 x 1 mm =0.1 mm 0.01 cm

In general if n Vernier division are equal to (n-1) scale divisions, then Vernier constant =

$$\text{VC} = \text{Value of } [1 \text{ S. D. } -1\text{V. D}].$$

$$= \text{Value of } \left(1-\frac{n-1}{n}\right)\text{S. D.} = \text{Value of } \frac{1}{n}\text{ S. D.}$$

If the m^{th} Vernier division coincide with any scale division, then the fraction to be added

$$= m \times \frac{1}{n}$$

To find the Vernier constant:

1. Find the magnitude of the smallest division on the main scale.
2. Slide the movable jaw so that zero mark (the first division) of the Vernier scale coincides with any one of the main scale divisions.
3. Count the total number of divisions on the Vernier scale.
4. Find the number of scale divisions, which coincide with the total number of Vernier divisions.

2. Linear Vernier:

i) Fortin's Barometer

Fortin's Barometer (Figure 2) is used to find the value of atmospheric pressure. In this instrument suppose 10V. D. coincides with 19 S. D. and the S. D. is 1 millimeter. To find Vernier constant each V. D. is supposed to be further divided into two, thereby making a total of 20 such Vernier constant.

$$20 \text{ V. D.} = 19 \text{ S. D.}$$

$$1 \text{ V. D.} = \frac{19}{20}\text{ S. D.}$$

Vernier Constant = VC = Value of (1 S. D.- 1V. D).

$$= \text{Value of } \left(1-\frac{19}{20}\right)\text{S. D.} = \frac{1}{20} \times 1 \text{ mm} = 0.05 \text{ mm} = 0.005 \text{ cm}$$

In fact such Vernier division is twice this supposed division

$$\text{V. C.} = 2 \times 0.05 = 0.1 \text{ mm} = 0.01 \text{ cm}.$$

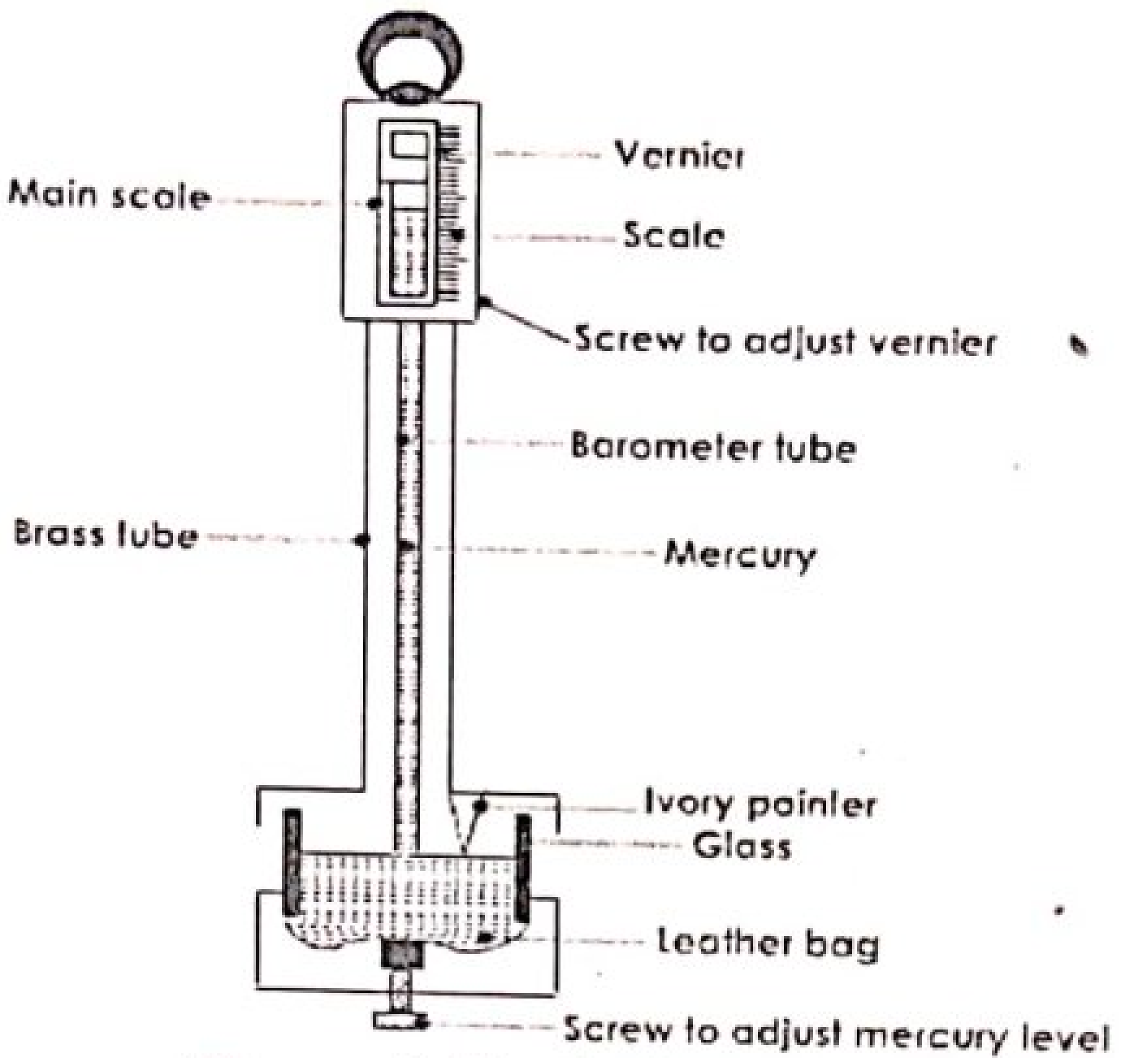

Main scale
Vernier
Scale
Screw to adjust vernier
Barometer tube
Brass tube
Mercury
Ivory pointer
Glass
Leather bag
Screw to adjust mercury level

Figure 2: Fortin Barometer

ii) Traveling Microscope

It is used for finding the length of very small objects. The traveling microscope (Figure 3) is first focused at one and then at the other end of the small object. The distance through which the microscope moves is measured by a Vernier rigidly fixed to the microscope and sliding over a centimeter scale.

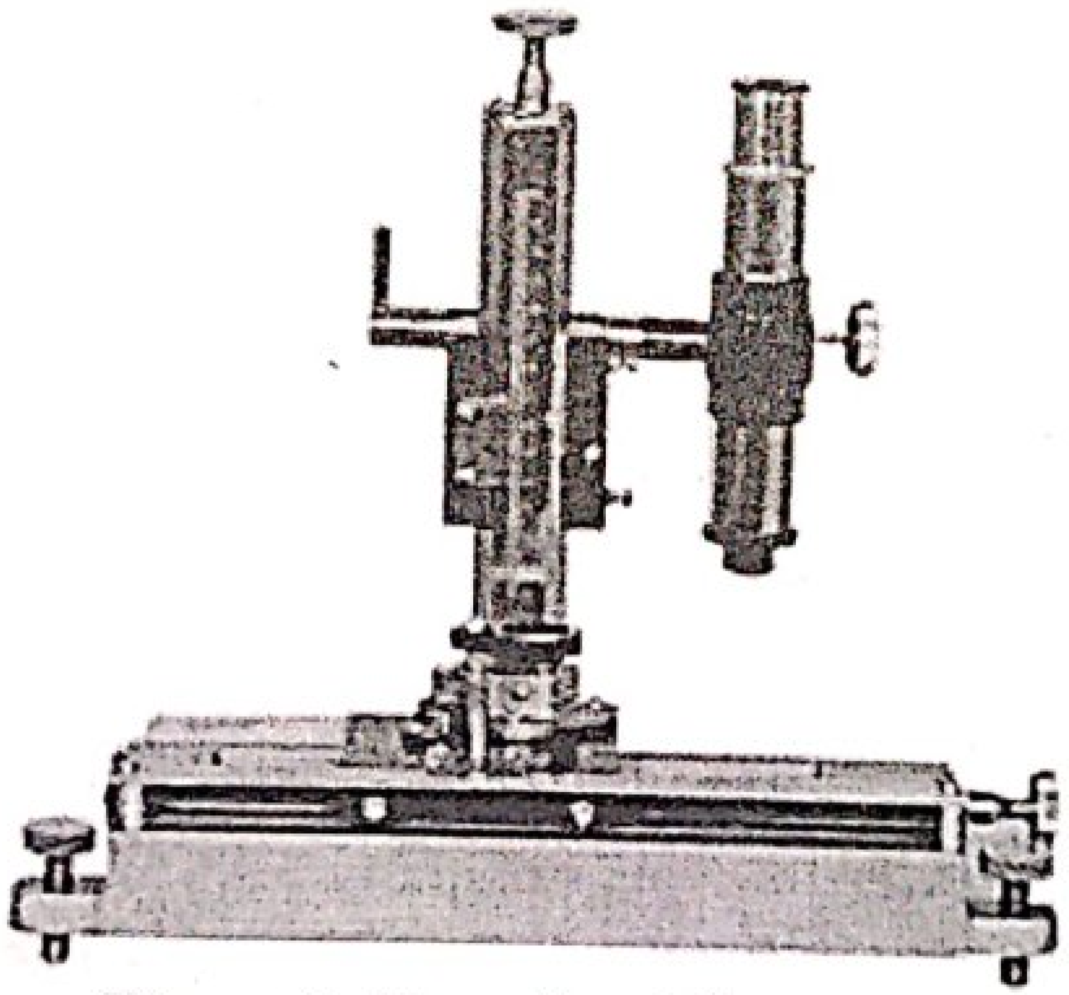


Figure 3: Traveling Microscope

In this case, suppose 50 V. D. coincide with 49 S. D. and each scale division is 0.5 mm.

$$50 \text{ V. D.} = 49 \text{ S.D.}$$

$$1 \text{ V. D.} = \frac{49}{50} \text{ S. D.}$$

Vernier Constant = VC = Value of (1 S. D. – 1V. D.)

$$= \text{Value of} \left(1 - \frac{49}{50}\right) \text{S.D.} = \frac{1}{50} \text{ x } 0.5 \text{ mm} = 0.01 \text{ mm} = 0.001 \text{ cm}$$

3. Circuler Vernier

Vernier used in spectrometer, sextants etc are called circular Vernier. The circle is divided into 360 degrees and each degree is further divided into 2, 5 or 6 parts.

i) Spectrometer

A spectrometer (Figure 4) is used to measure the refractive index by finding the angle of the prism and the angle of minimum division. In this case suppose 30 V. D. coincide with 29 S. D. and magnitude of each scale division is 0.5 degree.

$$30 \text{ V. D.} = 29 \text{ S.D.}$$

$$1 \text{ V. D.} = \frac{29}{30} \text{ S. D.}$$

Vernier Constant (VC) = Value of (1 S. D. – 1V. D).

$$= \text{Value of} \left(1 - \frac{29}{30}\right) \text{S. D.} = \text{Value of } \frac{1}{30} \text{S. D.} = \frac{1}{30} \times 0.5^0 = \left(\frac{1}{60}\right)^0 = 1'$$

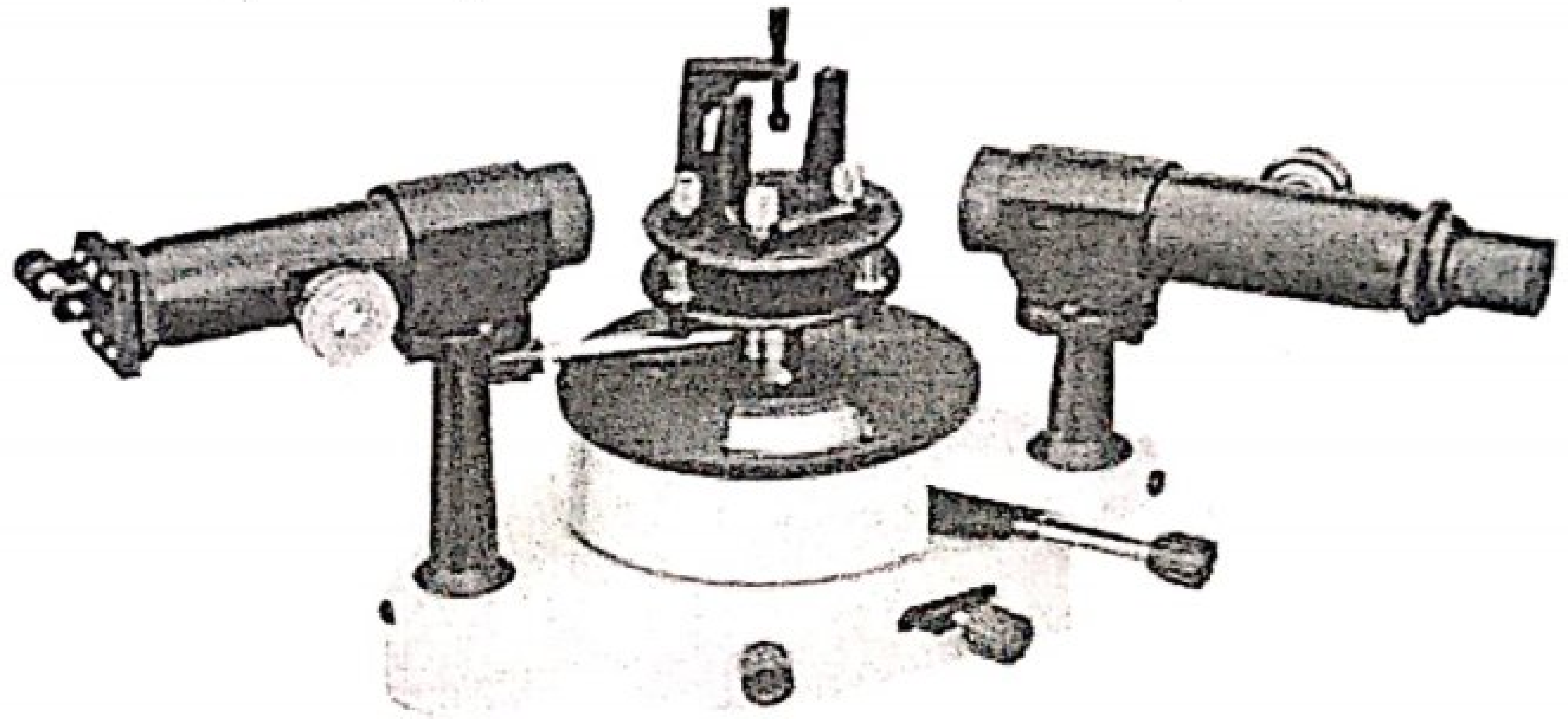


Figure 4: Spectrometer

ii) Sextant

A Sextant (Figure 5) is used to find the height of an object by measuring the angle subtended by it. In this case usually 120 V. D. coincide with 119 S. D. and each scale division is equal to 10 minute. To find the Vernier constant each Vernier division is supposed to be further divided into two thereby making a total of 120 such Vernier divisions.

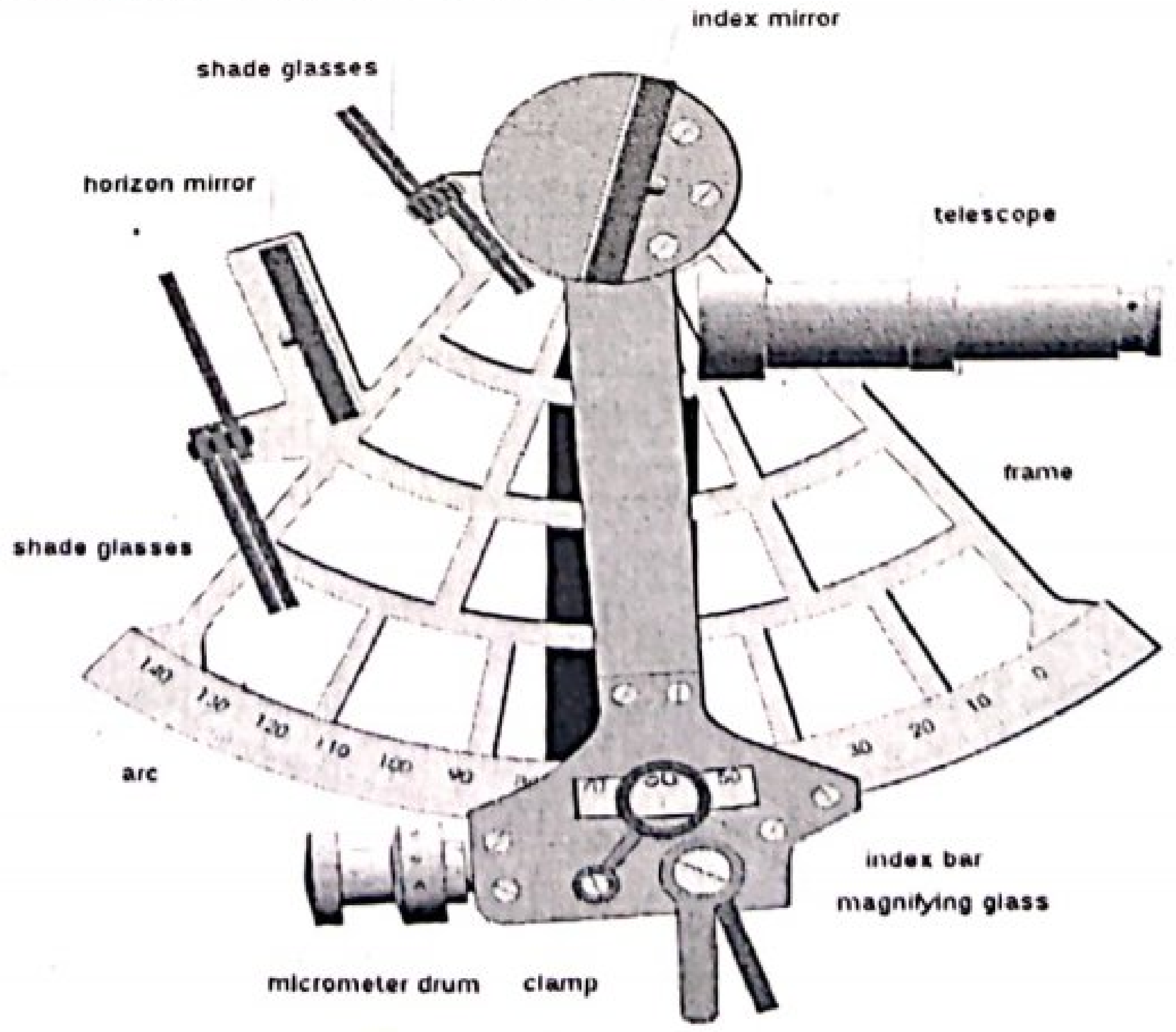

index mirror
shade glasses
horizon mirror
telescope
frame
shade glasses
arc
index bar
magnifying glass
micrometer drum
clamp

Figure 5: Sextant

$$120 \text{ V. D.} = 119 \text{ S. D.}$$

$$1 \text{ V. D.} = \frac{119}{120} \text{ S. D.}$$

Vernier Constant (VC) = Value of (1 S. D. – 1V. D)

$$= \text{Value of } \left(1-\frac{119}{120}\right) \text{S. D.} = \text{Value of } \frac{1}{120} \text{ S. D.} = \frac{1}{120}\times 10' = \frac{1}{12}\times 60' = 5''$$

In fact each Vernier division is twice this value, Vernier Constant = 2 x 5 = 10 seconds.

(c) Screw Gauge

The screw gauge (Figure 6) is very suitable for the measurement of small length such as the diameter of a wire. It consists of a V-shaped steel frame having two parallel arms at the ends.

i) Pitch of the Screw Gauge:

Pitch of a screw is defined as the distance between the two consecutive threads taken parallel to its axis and is measured by the distance through which the screw moves forward of backward when one complete rotation is giving to the circular cap.

To find the pitch:

1. Rotate the circular scale and coincide the zero mark with the reference line .Note the reading on the pitch scale.
2. Give four complete rotations to the circular scale and again note the reading on the pitch scale.
3. Calculate the pitch, $Pitch = \dfrac{Distance\ travel\ on\ the\ pitch\ scale}{Number\ of\ rotations}$

Note:- The pitch of a screw gauge is usually 0.5 mm or one millimeter.

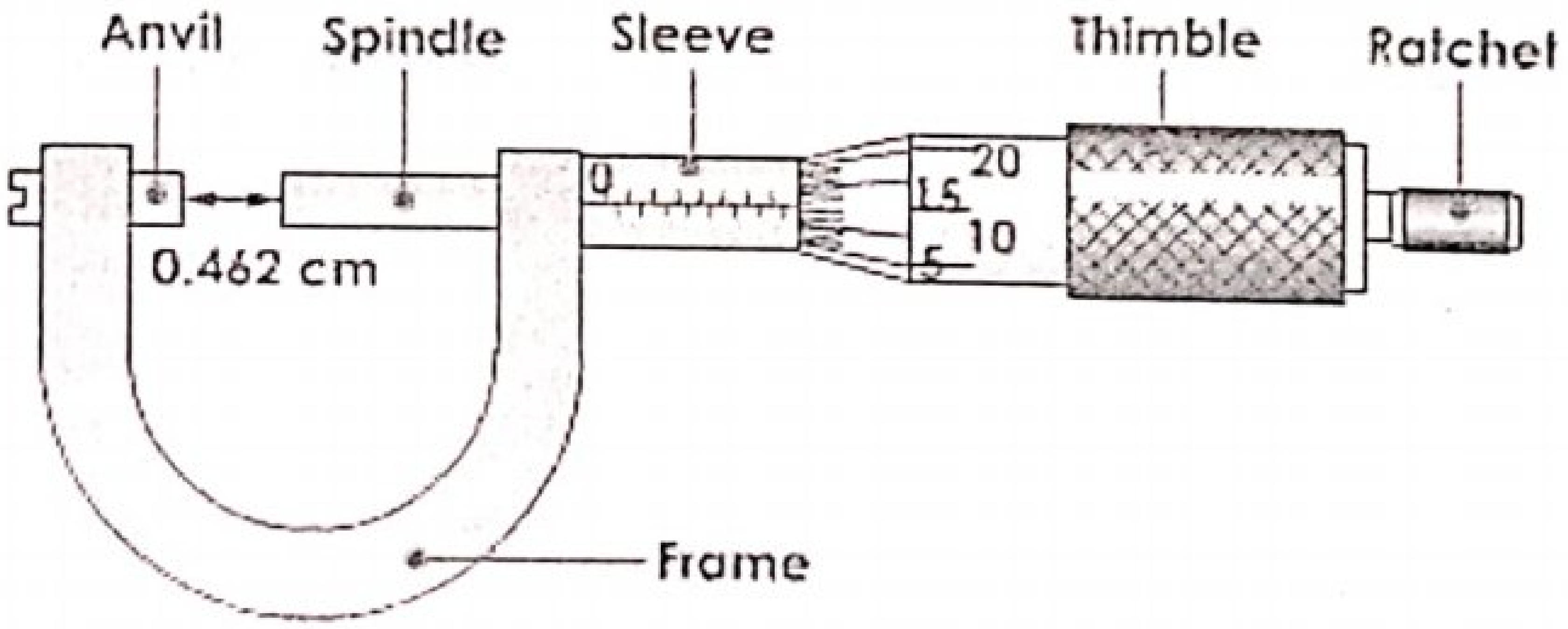


Figure 6: Screw gauge

ii) Least count:

The least count of the screw gauge is defined on the distance through which the screw moves backward or forward when the cap is rotated one division on the circular scale.

$$Least\ count = \frac{Pitch\ of\ the\ screw}{No.\ of\ division\ on\ the\ circular\ scale}$$

4. Instrumental Error

i) Zero Correction

Zero correction count the number of divisions on the circular scale by which the zero mark has advanced beyond or is left behind the reference line. Multiply these numbers with the least count. This is the zero correction. If the zero of the circular scale has advanced the reference line the zero correction is positive but if it is left behind the reference line it is negative.

ii) Back lash Error

This lag between the linear motion of the screw and the circular motion given to its head is called the backlash error rotated back it is first given a few rotation. This error can be avoided by turning the screw in the same direction while taking an observation. If the screw is to be rotations in the backward direction and then it is moved forward to the desired value. This eliminates the possibility of an error.

5. Spherometer

A spherometer (Figure 7) is an instrument used for measuring used for measuring very small distances. It also works on the principle of a micrometer screw. It is generally used for measuring the thickness of a thin plate and for determining the radius of curvature of spherical surfaces such as lenses or mirrors.

i) Least Count

The least count of the spherometer is the smallest distance that can be measured with it. It is the distance moved by the screw when it is turned through one the circular scale.
To find the least count of the spherometer:

1. Bring the zero of the circular scale against the division on the mm scale.
2. Give four complete rotations to the screw and find the distance moved by it on the millimeter scale.
3. Divide this distance by 4 to get the pitch of the screw.
4. Divide the pitch by the total number of divisions on the circular scale to get the 'least count' of the spherometer.

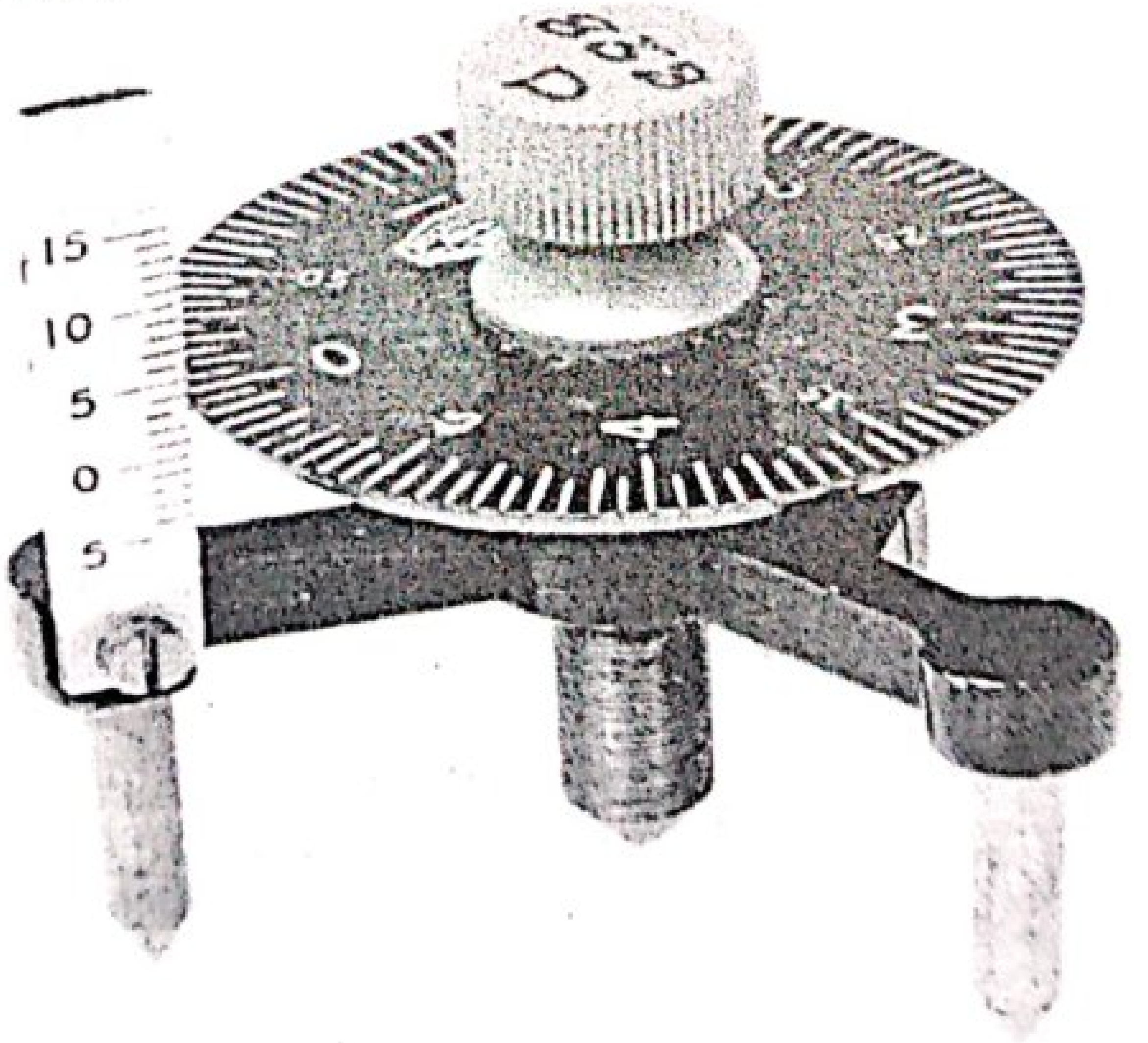


Figure 7: Spherometer

Calculation of least count
The main scale is graduated in millimeters. Pitch of the micrometer screw = 0.5 mm = 0.05 cm.
No. of divisions in the circular scale = 100

Least count of the instrument $= \frac{0.05}{100} = 0.0005cms$

When all the four legs of a spherometer are made to touch the spherical surface, the radius of curvature of the spherometer are made to touch the spherical surface, the radius of curvature of the spherical surface is given by

$$R = \frac{a^2}{6h} + \frac{h}{2}$$

Where a is the mean distance between the outer legs of the spherometer and h the high of the central leg above and below the place through the tips of the outer legs touch the lens.

6. Mass

The mass of a body is the quantity of matter contained in it. It is constant at all places and is found by comparing the weight of the body with that of the standard weights by an ordinary balance.
The weight of a body is the pull of the earth and varies from place to place. It is given by mg where m is the mass and g the acceleration due to gravity at the place.

7. Measurement of Time

We are familiar with a watch, a timepiece and a clock which are ordinary means of measuring time. In the laboratory we have to measure accurately the interval of time between two events. This is done with the help of a stop-watch or a stop clock.

8. Stop-Watch

It is a specially constructed watch having a long second's hand watch moves over a circular dial with sixty equal division marks representing seconds. Each division is further divided into 5 or 10 equal parts, thus enabling us to read correct up to 1/5th or 1/10th of a second. A small minute hand moves over a small circular dial graduated into 30 divisions, each representing a minute. For every complete rotation of the second's hand the minute hand advances by one division and one complete rotation of the minute hand is completed in 30 minute.
To begin with both the hands are at zero. At the beginning of an event as the knob at the top is pressed, the second's hand starts. At the end of the event the knob is again pressed when both the second's and the minute's hands stop. The interval of time can thus be read. If the knob is again pressed both the hands fly back to the zero position and the watch is ready for use.

9. Deviation

There are some errors in every measurement. The errors are of two kinds: The random errors and the systematic errors.
Random error: A random error is easy to assess and are generally taken to be reading errors and errors due to fluctuating experimental or environmental conditions. Random error is one, which varies and is equally likely to be positive or negative. This error may be detected by repeating the measurements.
Systematic error: Systematic error is a most difficult problem. If he true result is not known, it is only repeating experiments using different apertures in various combinations, or by comparison with the result of other workers, or by intelligent appraisal of the design of the experiment in relation to sources of error, that progress can be made in case of systematic errors. These are not reverted by one observer making repeated observations.
Suppose in the measurement of focal length of a convex or concave lens, the following observations are taken in cm. X_1, X_2, X_3, X_4, X_5,……………………etc.
The arithmetic mean = $\overline{X}$
Deviation of the following observations
$X_1 - \overline{X} = \delta_1$, $X_2 - \overline{X} = \delta_2$, $X_3 - \overline{X} = \delta_3$, …………………, $X_n - \overline{X} = \delta_n$

a) Average deviation

The average value of the deviations of all the individual measurements from the arithmetic mean is known as average deviation. The average deviation d is

$$d=(\delta_1+\delta_2+\delta_3+\delta_4\ldots\ldots\ldots\ldots\ldots\delta_n)/n$$

$$d=\left(\sum\delta_i\right)/n$$

Where n is the no. of observation

b) Standard deviation

A standard deviation is by far most important measure of dispersion. It is highly enabled to mathematical treatment and is comparatively stable under fluctuations of sampling. That it is not easily computed or readily understood is of secondary importance in the face of its overwhelming advantage. If computation is of prime concern the standard deviation is almost invariably used as a precise measure of dispersion.

Standard deviation is the positive square root of the mean of the squares of the deviation of the given values forms their mean. It is denoted by σ (sigma). Mathematically it is denoted as:

$$\sigma=\sqrt{\frac{\sum_{i=1}^{n}\left(X_i-\overline{X}\right)^2}{n(n-1)}}$$

Where,

σ = Standard deviation

n = number of observation

X_i = individual observation

$\overline{X}$ = mean value

Standard deviation is affected at least by fluctuation of sampling.

Experimental results

Actual value of the experimental observation, X= $\overline{X}\pm\sigma$

Percentage of error

$$\text{Percentage of error}=\frac{X\sim Y}{Y}\times 100$$

Where Y is the supply value of the Experiment,

The example is given below for calculating the standard deviation of the frequency of a tuning fork. Suppose the frequencies are 76.48, 74.48, 75.16, 75.0, 72.50 and 74.49.

Table 1: Calculation of standard deviation (**Given as an example only**)

X_i	$\bar{X}$	$(X_i-\bar{X})$	$(X_i-\bar{X})^2$	$\sum(X_i-\bar{X})^2$	n	σ
76.48		1.83	3.3489			
74.48		-0.17	0.0289			
75.16	74.65	0.51	0.2601	8.8485	6	0.54
75.0		0.35	0.1225			
74.49		-0.16	0.0256			
72.50		-2.25	5.0625			

Experimental Results = Arithmetic mean $\pm\sigma$

$$=74.65\pm0.54=75\ or\ 74$$

Analytical Balance

An analytical balance is used to find the mass of a body by comparing its weight with that of standard weight from a weight box.

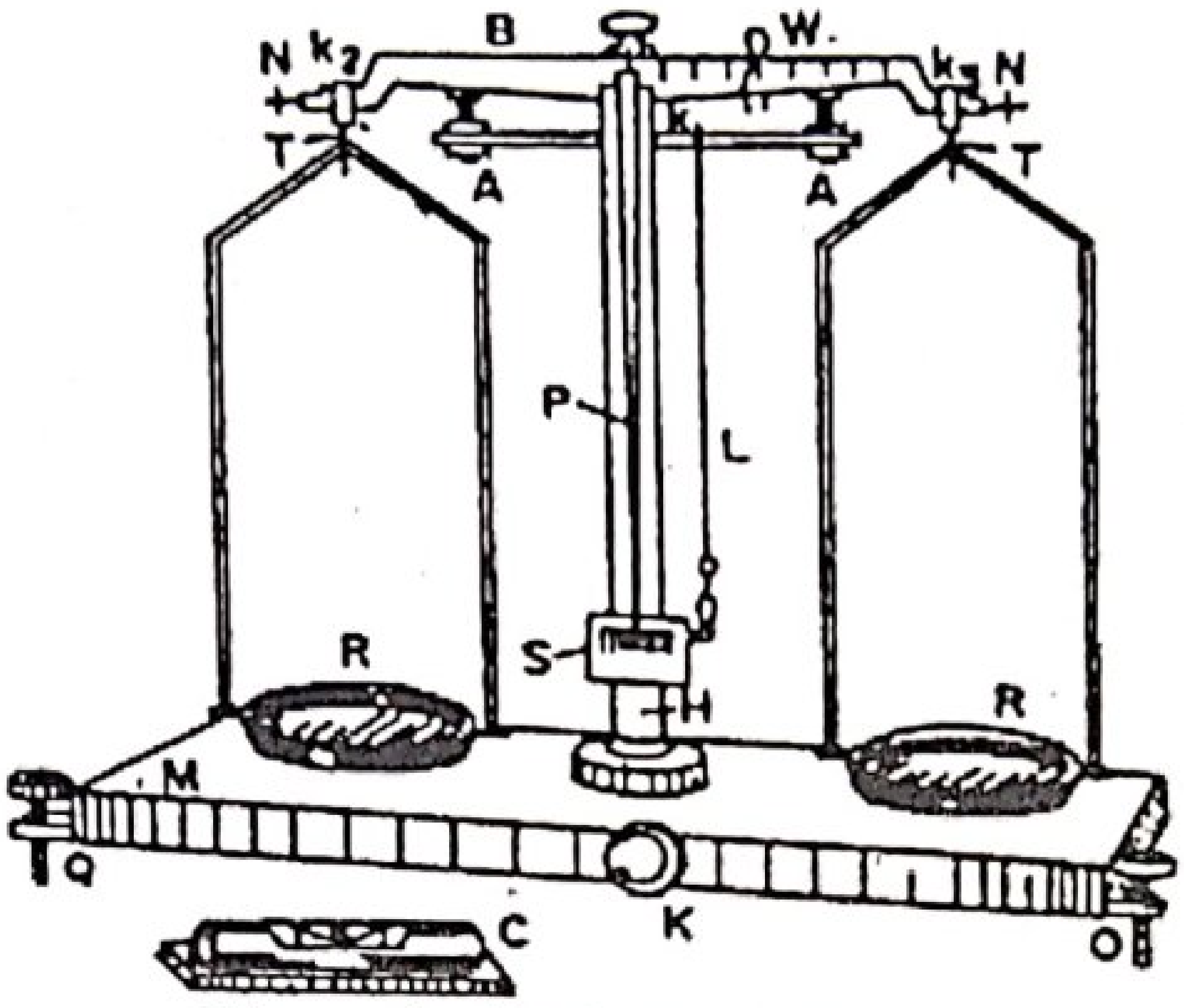


Figure 1: Analytical Balance

Precautions of using a balance:

i. Clean the scale pans of the balance with a soft brush or handkerchief.
ii. Make the plumb line vertical with the leveling screws.
iii. Close the shutter of the balance and turn its lever gently, so that the pointer oscillates freely on both sides of the central mark. Note the position where the pointer comes to rest. The resting point should be within one division on either side of the central mark. If it is not, adjust the screw nuts at the ends of the beam.
iv. Place the body to be weighted in the left-hand pan and put standard weights from the weight box in the right pan. Hold the weights with a pair of forceps only and take care that the weights are either placed in the pan or in the weight box and no elsewhere.
v. While adding a weight in the pan or removing it from the pan turns the lever gently to stop the motion of the beam and the pointer.
vi. Never weight hot bodies.
vii. Close the balance of all sides while taking a reading or when showing the weight to the examiner.
viii See that the lever meant for carrying the rider does not touch the beam.
ix Always close the door of the balance case and the weight box after finished the experiment.

EXPERIMENT 2

To Weight of a Body by the Method of Oscillation

Theory:

Due to the knife-edge supports of the beam of a balance, friction is reduced to a minimum. Hence while the beam is set free the pointer oscillates over the scale and takes a long time to come to its final position of rest.

The resting point may be determined by the method of oscillation without waiting for the pointer to come to rest. This is done by observing the turning point of the pointer for complete number of oscillation (say two), so that an odd number of reading (say five) is obtained. The zero of the scale is placed at its left end. As the pointer moves, there readings of the pointer are taken to the left (say) and two reading to the right. The mean of the left-hand readings and that of the right hand readings is found out. Finally the mean of these two mean readings is calculated. This represents the resting point, let it be P.

The resting point of the unloaded balance is P.

The resting point of the loaded (w) balance is Q.

The resting point of the loaded (w + 10 mg) balance is R.

Then for a change of load 10 mg, the shift in the position of rest is (Q – R) or pointer shifts one division for adding of

$$\left(\frac{10}{Q-R}\right)mg$$

For (Q-P) division shift, the change of load is

$$\left(\frac{10}{Q-R}\right)\times(Q-P)mg$$

$$\left(\frac{Q-P}{Q-R}\right)\times\left(\frac{10}{1000}\right)gm$$

$$\left(\frac{Q-P}{(Q-R)\times 100}\right)gm$$

Thus the weight of the body is $W_0 = W + \frac{Q-P}{(Q-R)\times 100} gm$ (1)

Apparatus: Analytical balance, weight box, a mass to be weighted:

Procedure:

i. Imagine the zero mark at the extreme left end graduated on the scale.

ii. Carefully set the beam of the balance free by turning the lever so that the pointer swings freely over the scale.

iii. The resting point of the pointer is determined for an unloaded balance and this is repeated for three times and the mean of three gives the value of P.

iv. Then by placing the body on the left hand pan and suitable weights W on the right hand pan, the resting point is again determined for three times. Left the mean of three times. Let the mean of these resting points is Q.

v. By placing additional weight 10 mg, the resting point is again determined for three times. Let the mean of these three resting points be R.

vi. After calculating the resting point P, Q, R the true weight w_0 will be calculated using the eq^n 1.

Table 1: Data for the weight of a body

No. of obs.		Load on Pans		Reading of the pointer		Mean Reading		Resting points (x+y)/2	Mean resting points
		Left	Right	Left	Right	Left	Right		
1.	i)	0	0						P=?
	ii)	0	0						
	iii)	0	0						
2.	i)	Body	W=						Q=?
	ii)	,,	,,						
	iii)	,,	,,						
3.	i)	,,	W+10mg						R=?
	ii)	,,	,,						
	iii)	,,	,,						

Calculation: $W_0 = W + \frac{(Q-P)}{100(Q-R)} gm$

Discussions: See precautions of using a balance

Experiment 3

To Draw a Graph for showing the Sensitivity of a Balance with Loads

Theory:

The sensitivity of a balance is quantitatively defined as the angle turned through by the beam (or the pointer) when the difference of weights in the two pans is one milligram.

$$\text{Sensitivity of a balance} = \frac{d}{w}$$

Where, d is the deflection of the pointer on the scale and w is the difference of weight in the two pans in milligrams. In Figure1 AB indicates the beam of the balance and AO = BO =a, are its arms. Let us suppose that the beam is deflected by an angle by the addition of an excess load of magnitude w gm on the right pan.

If pp' = d be the displacement of the pointer on the scale S, than θ= d/1, where 1 is the length of the pointer. The whole weight of W gm of the beam (w x 100 mg) however is considered to act at its center of gravity G. This distance of the center of gravity from the fulcrum O is CG = h.

The moment of excess load w about O is $wa\cos\theta$ and the moment of W about O is $1000Wh\sin\theta$.

For equilibrium of the beam the moments are equal.

$$1000Wh\sin\theta = wa\cos\theta$$

$$\frac{\sin\theta}{\cos\theta} = \frac{wa}{1000Wh}$$

$$\tan\theta = \frac{wa}{1000Wh}$$

As θ is small, than $\tan\theta \approx \theta = \frac{d}{l}$

Hence $$\frac{d}{l} = \frac{wa}{1000Wh}$$

Therefore the sensitivity of the balance $$\frac{d}{w} = \frac{al}{1000Wh} \qquad (1)$$

From equation (1) it is clear that sensitivity can be increased by

(i) Making the arms 'a' long

(ii) Decreasing the weight 'W' of the beam and

(iii) Diminishing 'h' i. e. by raising the CG of the beam near the fulcrum.

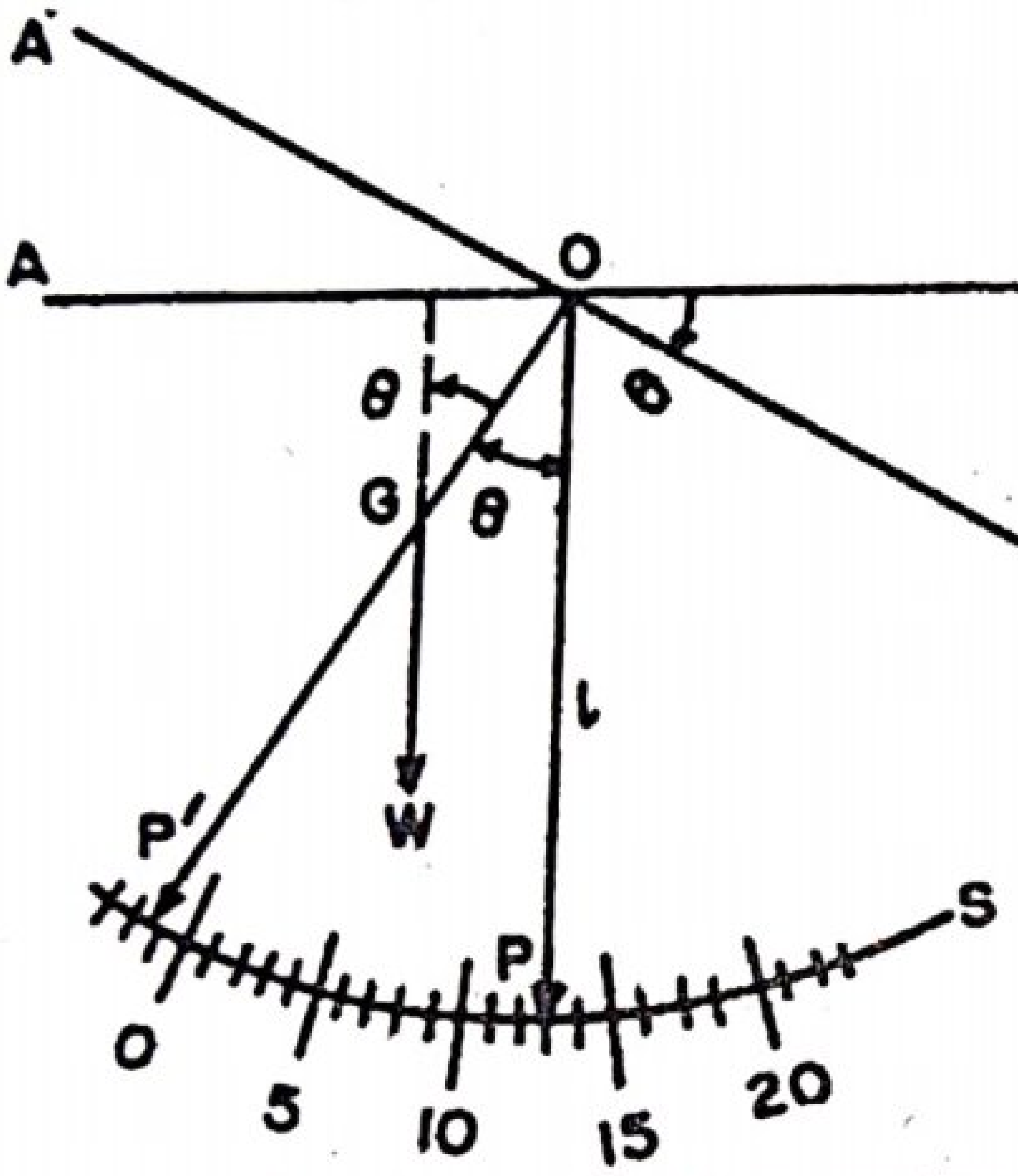


Figure 1: Showing oscillation to take reading

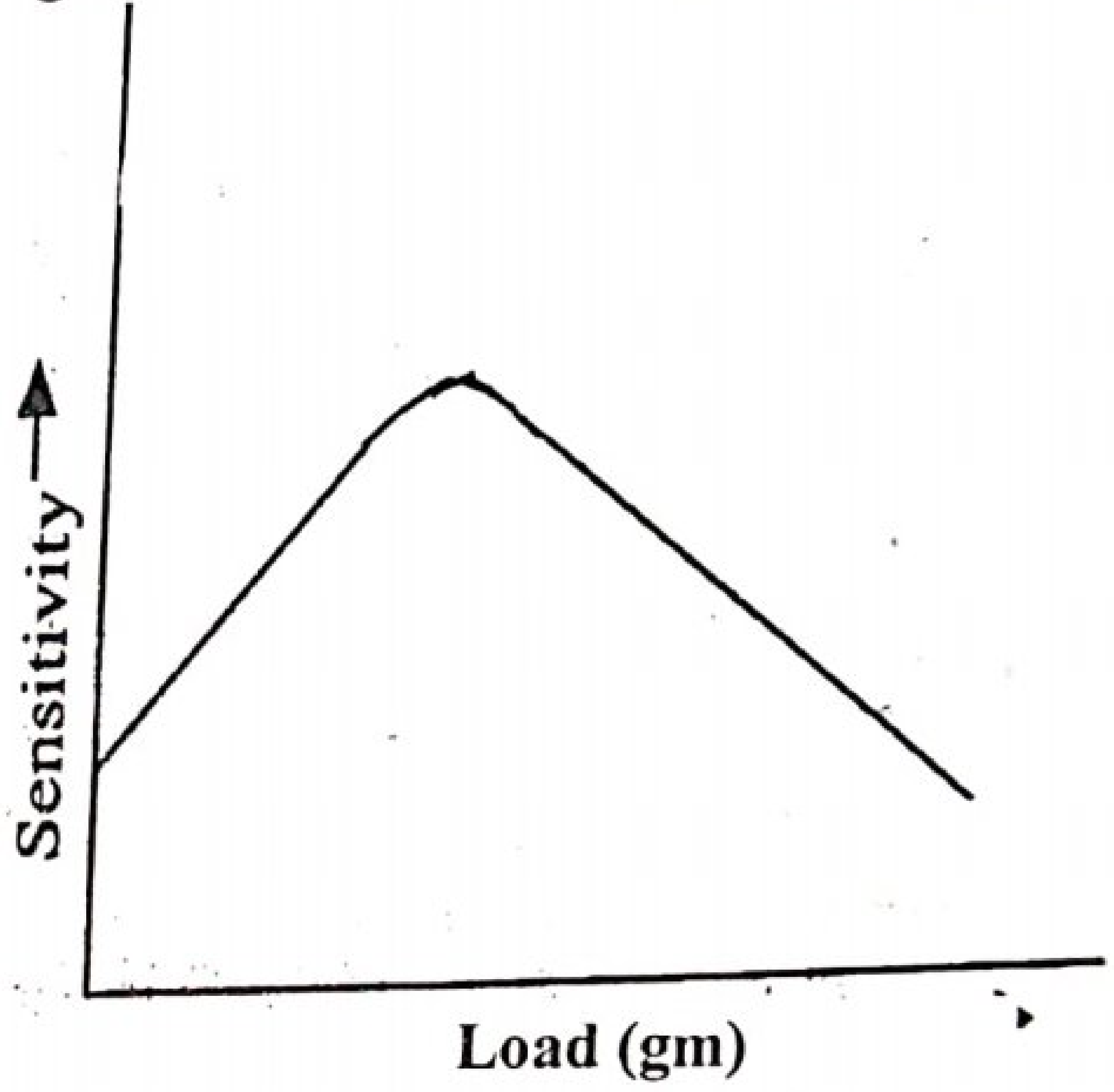


Figure 2: Load on each pan in gms.

In our laboratory work, at the beginning both the pans of the balance are kept unloaded and the resting point of the pointer is determined by P. The resting point of the pointer is again determined by adding an extra load 10 mg on the right pan is Q.

The deflection of the pointer on the scale = d = (Q-P) and the difference of weight in the two pans in milligrams = w = 10 mgs.

Sensitivity of a balance = $\frac{d}{w} = \frac{Q-P}{10}$ scale divisions/mg

Apparatus:

An analytical balance, weight box, a mass to be weighted

Procedure:

1. At first we take two complete oscillations without addition of any weight in the pan of a balance. The mean of the three readings to the left as well as the mean of the two readings to the right is determined. The mean of these two readings will give the resting point of the pointer (P).
2. Place a load of 10 mg on the right pan and determine the resting point of the pointer (Q). The sensitivity of the balance for zero loads of the pans will be given by equation (3).
3. Now place a load of 10 gm on the left pan and a load of 10 gm on the right pan and again determine the mean resting point (P), then place an excess load of 10 mg in the right pan and determine the resting point (Q) of the pointer. From these two mean resting points, calculate the sensitivity of the balance as in operation (3) above.

4. Similarly, determine the sensitivity of the balance for the loads **20, 30, 40, 50, 60, 80, 100, 120 and 140** gms on each pan.
5. Draw a graph with load as abscissa (x- axis) and corresponding sensitivity as ordinate (y-axis) as shown in Figure 2

Table 1: Data for sensitivity of a balance

No. of obs.	Load on Pans		Reading of the pointer		Mean Reading		Resting points= (x+y)/2	Sensitivity $(Q-P)/10$ sd/mg
	Left	Right	Left, x	Right, y	Left, x	Right, y		
1	0	0					P	
	0	10 mg					Q	
2	10 gm	10 gm					P	
	10 gm	10gm+10 mg					Q	
3	20 gm	20 gm					P	
	20 gm	20gm+10 mg					Q	
....	.....	....	....	.....	.....	.....	.....	....
	.....	.....	......	.....	......	.....	......	.....
N	140 gm	140 gm					P	
	140 gm	140gm+10 mg					Q	

Discussions:

It is to be noted that the sensitivity of a balance becomes maximum if the three knife edges lie in one horizontal line. But usually the plane of the extreme knife edges k_2 and k_3 remain above the central knife-edges k_1 and hence the sensitivity is now less than the maximum value. This increases the sensitivity of the loads on the pans are sufficient to lower the plane of the extreme knife-edges below the central knife-edge k_1, the sensitivity again decreases. The nature of variation of sensitivity of balance is shown in Figure2 beginning with the position of the central knife-edge below the plane of the extreme knife-edges.

Precautions of using a balance:

i) Cleanse the scale pans of the balance with a soft brush or handkerchief.
ii) Make the plum line vertical with the leveling screws.
iii) Close the shutter of the balance and turn its lever gently, so that the pointer oscillates freely on both sides of the central mark. Note the position where the pointer comes to rest. The resting point should be within one division on either side of the central mark. If it is not, adjust the screw nuts at the ends of the beam.
iv) Place the body to be weighted in the left-hand pan and put standard weights from the weight box in the right pan. Hold the weights with a pair of forceps only and take care that the weights are either placed in the pan or in the weight box and on elsewhere.
v) While adding a weight in the pan or removing it from the pan turns the lever gently to stop the motion of the beam and the pointer.
vi) Close the balance of all sides while taking a reading or when showing the weight to the examiner.
vii) See that the lever meant for carrying the rider does not touch the beam
viii) Always close the door of the balance case and the weight box after finished the experiment.

Oral Questions and their Answers:

Q1. What is the difference between mass and weight?

Ans. The mass of a body is the quantity of matter contained in it, and the weight of a body is the pull of the earth by the gravitational force and varies from place to place. Mass is constant everywhere, because it does not depends on the earth's attraction.

Q2. What do you measure with a balance?

Ans. Mass is measured by comparing its weight with that of standard 'weights' from a weight box.

Q3. What are the requisites of a good balance?

Ans. A good balance must be true, sensitive, stable and rigid.

Q4. What is the condition that a balance may be true?

Ans. i) The pans must be of equal weight and
ii) The arms of the beam must be of equal lengths.

Q5. Why are the beam and the pans of a balance supported by knife-edges by a gate plate?

Ans. In order to diminish the friction of working parts of support and suspension.

Q6. When will the beam of the balance be horizontal?

Ans. When the moment of the weight of the body to be weighted and that of the standard weight about the fulcrum are equal.

Q7. Is the weight of a body constant at various places on the surface of the earth?

Ans. No, it varies from place to place. It decreases when the body is taken (i) at high altitude (ii) in deep mine (iii) from pole to equator. At the center of the earth it vanishes.

Q8. Why do you close the shutter of the balance?

Ans. Close the shutter and turn the levers, the pointer oscillate equally on both sides of the control mark.

Q9. How does sensitivity very with load?

Ans. See Figure 2

Q10. What is sensitivity of a balance?

Ans. See the text.

Q11. What are the advantages of the method of oscillation?

Ans. In a very sensitive balance the pointer goes on oscillating about the mean position for a long time and the resting point can be readily calculated by the method of oscillation.

Q12. What are the conditions for sensitiveness of balance?

Ans. (i) The arms of the beam must be long.
(ii) The distance of the center of gravity of the beam from the central knife-edge must be small.

Q13. What are the conditions for a balance said to be stable?

Ans. (i) The arms of beam must be small.
(ii) The distance of the center of gravity of the beam from the central knife-edge must be large and
(iii) The beam must be heavy.

Q14. Why are the weights put on the right hand pan and the body on the left-hand pan?

Ans. The weights are to be varied and for convenience of putting them, they are placed on the right hand pan.

Experiment 4
To Determine the Young's Modulus and the Rigidity Modulus of a short write by Searle's Dynamic Method

Theory:

Determination of Young's modulus:

The ends of the two bars L and P are slightly pulled together symmetrically of the Searle's apparatus for finding the elastic constant (Figure 1). If a wire was fastened to two identical bars at their mid points from which they are supported by threads. If the ends of the bars are drawn together and released, the bar oscillates with a time period T_1. Vibration will depend upon the moment of inertia of the oscillating system, the dimension of the experimental wire and the Young's modulus of elasticity of the wire. Let θ be the angle through which each bar is displaced at any instant of time (Figure 1). Let R be the radius of curvature of the wire at this instant of time.

$$\therefore l = R \times 2\theta$$

Restoring couple $= \dfrac{YI_g}{R}$ and Deflecting couple $= I\alpha$

For circular cross section $I_g = \dfrac{\pi r^4}{4}$

Therefore, the restoring couple $= \dfrac{Y\pi r^4 \times 2\theta}{4l}$

For equilibrium, Restoring couple=Deflecting couple

$$T_1 = 2\pi\sqrt{\frac{2Il}{Y\pi r^4}} \quad \therefore Y = \frac{8\pi Il}{T_1^2 r^4}$$

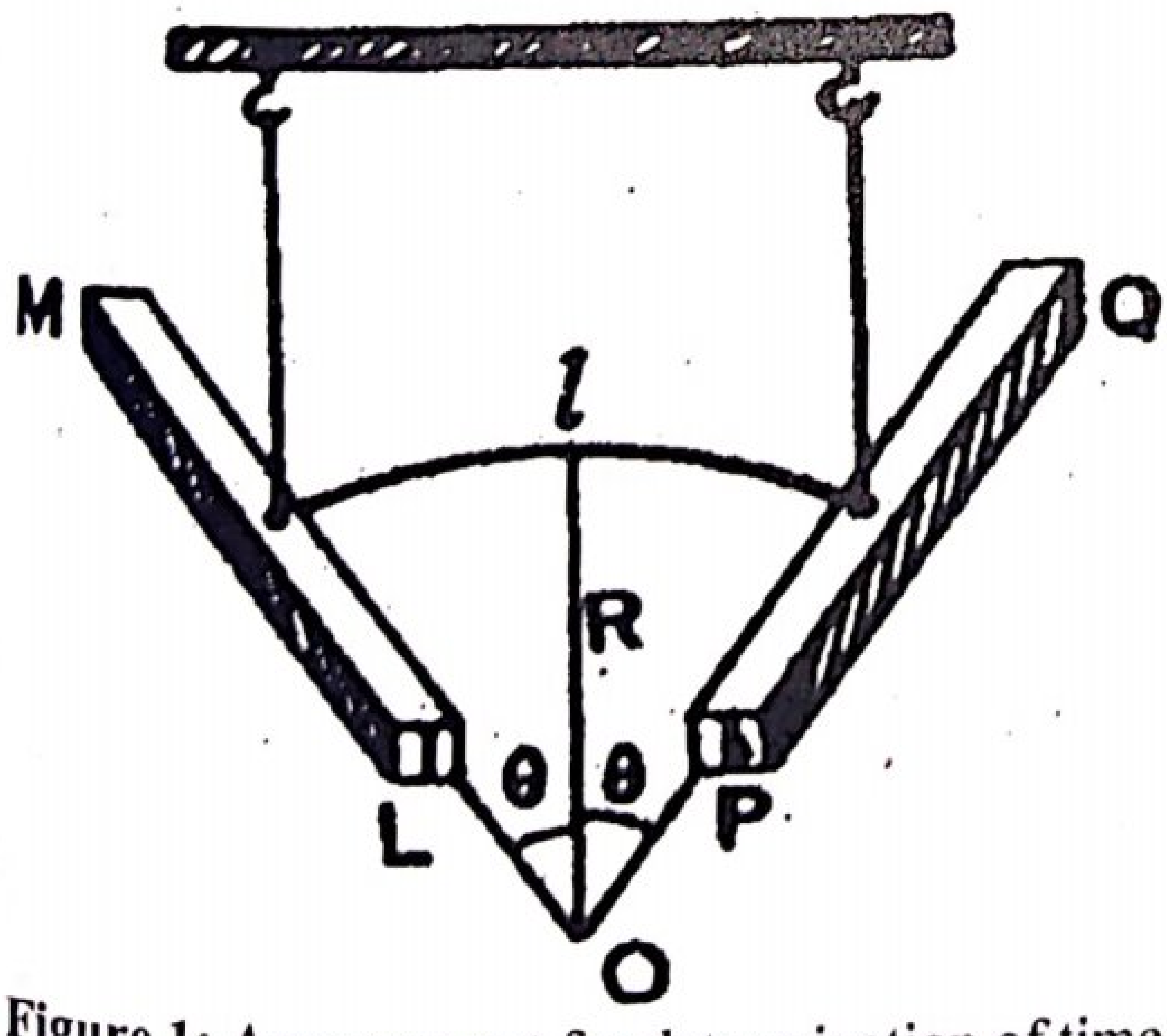


Figure 1: Arrangement for determination of time period T_1

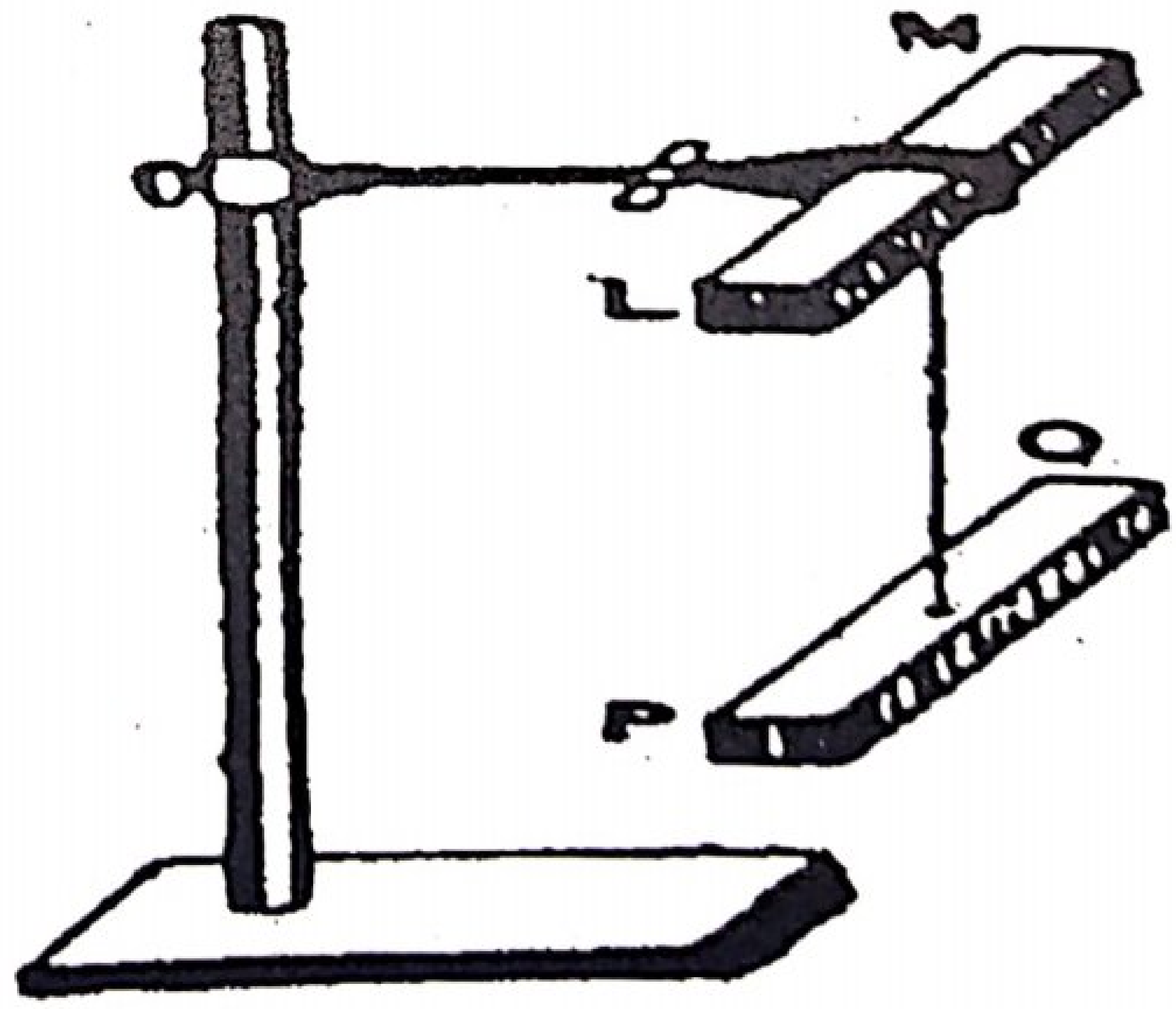


Figure 2: Arrangement for determination of time period T_2

Where I is the moment of inertia of the bar about on axis passing though its center of gravity and perpendicular to its length, l is the length of the wire, r its radius and Y the Young's modulus of the materials.

Determination of Rigidity Modulus:

If the suspension threads are removed and one of the bars is clamped so that the other hangs in the horizontal plane as show in Figure 2. If a little twist will be given on the hanged bar then it will execute torsional oscillations of time period T_2 is given by

$$T_2 = 2\pi\sqrt{\frac{I}{C}}$$

Where C is the coupled exerted by the bar per unit angular twists.

If η is the modulus of rigidity of the wire, then $C = \frac{\pi\eta r^4}{2l}$

$$\therefore T_2^2 = \frac{4\pi r^4}{C} = \frac{4\pi^2 \times 2Il}{\eta\pi r^4} = \frac{8\pi^2 Il}{\eta\pi r^4} \qquad \text{Therefore, } \eta = \frac{8\pi^2 Il}{T_2^2 \pi r^4}$$

Apparatus: Searle's apparatus, thread, stop watch, screw gauge, a meter scale, slide calipers etc.

Procedure:

i) Determine the diameter of the wire at several places, with the help of a screw gauge very carefully at several places and then calculate the mean radius of the wire.

ii) Measure the width of the bar b with a slide calipers and calculate the moment of inertia of the bar.

iii) The arrangement of the apparatus is in equilibrium positions, suspend the two bars from rigid supports, by two threads of suitable lengths so that when the system is at rest the two bars and the wire lies in the same horizontal plane.

iv) Pull the ends L and P of the rods ML and QP from their position of rest with a thread (Figure 1) and then burn the thread. The bar will begin to oscillate. With the help of a stopwatch count the time for 40, 35, 30, 25, and 20 oscillations. Then calculate the mean period of oscillations T_1.

v) Remove the bars from the suspended threads and clamp one of the bars as shown in Figure2, so that the wire is vertical and second bar is horizontal. Twist the wire by rotating the lower bar so that it begins to execute torsional vibrations. Find the time for 30, 26, 24, 22, 20, 18, and 16 oscillations with the help of a stop watch. Calculate the mean time period of oscillation T_2.

Experimental Data:

A. **Data for length of the wire:**

l_1=............cm, l_2= ....cm, l_3= ....cm

Mean length of the ware, $l = \frac{l_1 + l_2 + l_3}{3}$ =......cm

B. **Data for the radius of the string:**

Value of the smallest division of the linear scale = pitch of the screw =.......cm
Least count of the Screw gauge

$$= \frac{Pitch\ of\ the\ screw}{No.\ of\ divisions\ on\ the\ circular\ scale} = ...cm$$

Table 1: **Data for diameter of the wire**

No. of obs.	Linear scale reading L (cm)	Circular scale divisions C	Least Count, V (cm)	Value of circular scale div. $V \times C$ cm	Total readings, $D = L + V \times C$ cm	Mean Diameter D (cm)
1						
2						
3						
4						

Radius $r = \frac{D}{2} =$……cm

Table 2: Data for the width of the bar b

No. of obs.	Linear scale reading M (cm)	Vernier scale divisions, V	Vernier constant C, cm	Vernier scale reading $V \times C$, cm	Total width $M + (V \times C)$ cm	Mean width b, cm
1						
2						
3						
4						

Moments of inertia of the Bar: $I = \frac{M}{12}\left(L^2 + b^2\right)$ gm.cm^2

Length of the bar, L =………cm
Mass of the bar, M =………gm

Table 3: Calculation of Time period, T_1

No. of observations	No. of vibrations	Total time in seconds	Time period T_1 seconds	Mean T_1 seconds
1				
2				
3				
4				

Table 4: Calculation of Time period, T_2

No. of observations	No. of vibrations	Total time in seconds	Time period T_2 seconds	Mean T_2 seconds
1				
2				
3				
4				

Calculation:

1. Young's modulus Y =………dynes/cm^2
2. Rigidity modulus η =………dynes/cm^2

Discussion:

i) Care should be taken that the wire is not strained beyond the elastic limits and the thread remains vertical.

ii) The bars should vibrate in a horizontal plane and there should be no up and down motion.

iii) The radius of the wire should be measured very accurately. In the calculations it occurs as the fourth power and a small error in its value will magnified four times.

iv) Short length of the wire is used and so the value of Y is more accurate than the long wire.

v) The value of oscillation counts should be accurate for measuring the time periods in both cases.

vi) Number of oscillation counts should be accurate for measuring the time periods in both cases.

Oral question and their Answers:

Q1. Define stress, strain and Young's modulus of elasticity.

Ans. Stress: The restoring force per unit area acting on the body is called stress. Stress = F/A

Strain: The ratio of change in dimension, to its original dimension is called strain. Strain is thus a pure ratio and has no unit.

Young's modulus: The ratio of normal stress to longitudinal strain with its elastic limit is called

$$\text{Young's Modulus, } Y = \frac{Stress}{Strain} = \frac{F/A}{l/L} = \frac{FL}{Al}$$

Q2. What do you mean by elastic limit and breaking stress?

Ans. Elastic limit: - This maximum stress up to which a body exhibits the property of elasticity is called the elastic limit.

Breaking stress: - The breaking weight per unit area of cross-section is called the breaking stress.

Q3. Which is more elastic rubber or steel?

Ans. Steel is more elastic than Rubber.

Q4. Define modulus of rigidity? What is the unit of rigidity?

Ans. The ratio of the tangential stress to the shearing strain is called rigidity of modulus.

Q5. What is the effect of temperature on rigidity?

Ans. The property of solid is to resist the forces tending to change its shape with increasing temperature. However rigidity modulus changes with changing temperature.

Q6. What is moment of inertia?

Ans. The sum of the product of the mass and the square of the distance of different particles of the body from the axis of rotation is called moment of inertia.

Q7. How do the pendulum oscillations and torsional oscillations differ?

Ans. The pendulum oscillations are controlled by gravity and the torsional oscillations are controlled by amount of torsion in the suspending wire.

Q8. What is the advantage of this method?

Ans. Here Y is evaluated by counting time and not deflection. Another advantage is that it requires a very short specimen, η is also determined simultaneously.

Q9. Define tangential stress, tangential strain, shearing stress and shearing strain and compare Y and η.

Ans. See the text book, you will find it from theory.

Q10. What are the two types of oscillations occur in this experiment?

Ans. There are two types of oscillations occur in this experiment. i) Pendulum oscillations/ simple harmonic oscillations and ii) Torsional oscillations.

Q 11. Define Hooke's law of elasticity. Draw the stress-strain diagram and explain the behavior of material under stress.

Ans. See the text book, you will find it from theory.

Experiment 5
To Determine the Surface Tension of Water by Capillary Tube Method

Theory:

Capillary tubes of radius r open at both ends and dipped vertically into a liquid, which wets the walls. The liquid rises up the tube through a height h, the surface of the liquid in the capillary tube would assume a spherical shape and for this liquid it will be concave upward. Let it make an angle θ with the vertical wall of tube, then θ is the angel of contact and a force T due to surface tension acts along the tangent at A which is the point of contact of the liquid with the walls.

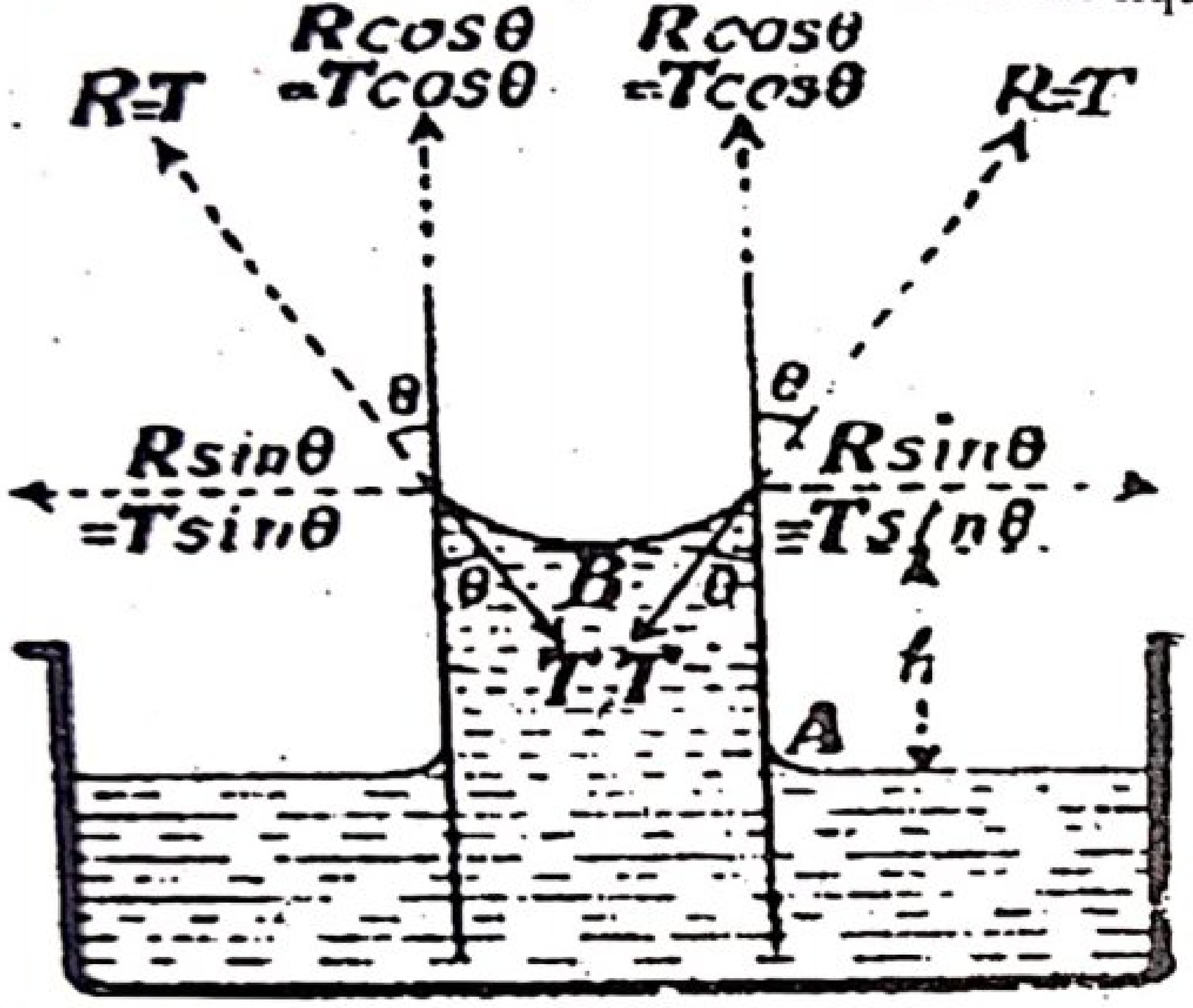


Figure 1: Height of Water meniscus

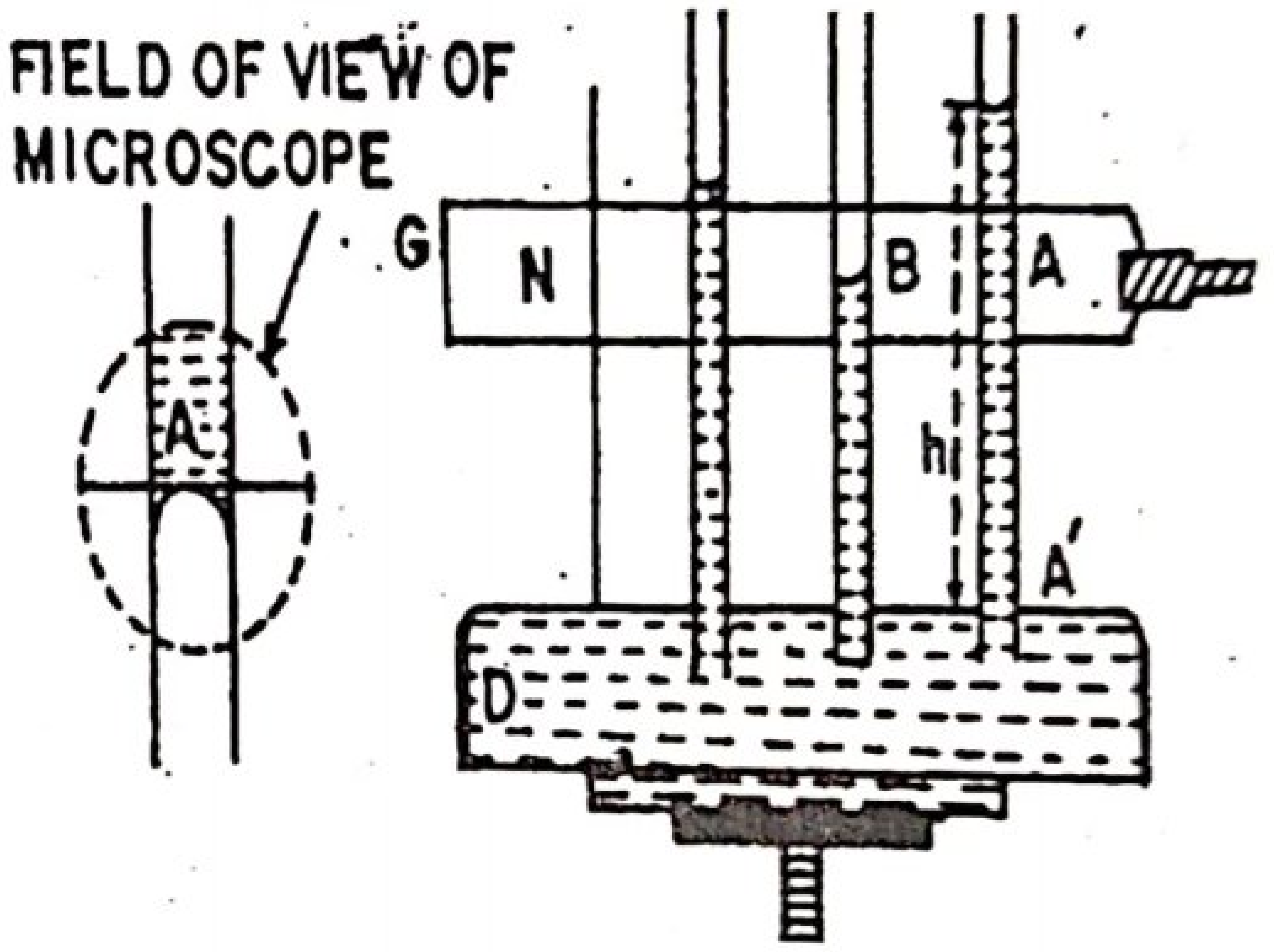


Figure 2: Capillary tubes of different diameter

The total vertical component of the force acting in the upward direction is $2\pi rT\cos\theta$, r being the internal radius of the capillary tube. This upward force supports the weight of the liquid column.

The volume of the liquid = $\pi\left(r^2h+\frac{r^3}{3}\right)$

If ρ is the density of the liquid and g is the acceleration due to the gravity then the total weight of liquid column = $\pi r^2\left(h+\frac{r}{3}\right)pg$

In equilibrium position $2\pi rT\cos\theta = \pi r^2\left(h+\frac{r}{3}\right)pg$

Surface tension, T = $\frac{r^2\pi\left(h+\frac{r}{3}\right)g\rho}{2r\pi\cos\theta} = \frac{r\left(h+\frac{r}{3}\right)g\rho}{2\cos\theta}$

For water θ is almost small, then $\theta = 0$ and $\cos\theta = 1$

$$T = \frac{1}{2}\,p\,g\,r\left(h+\frac{r}{3}\right) dynes/cm$$

Apparatus: Capillary glass tube, glass strip, a needle, a beaker, adjustable clamp stand, a thermometer, a traveling microscope, and magnifying glass.

Procedure:

i) Select three capillary tubes of different diameter (Figure 2). Clean the bore of the tube carefully with hydrochloric acid and then with caustic soda and finally wash by passing water through it.

ii) Mount it on a glass strip with wax as shown in Figure 2. Also mount a thin needle with a sharp end on the side of the glass strip parallel to the capillary tube so that its fine end projects a little less than that of the capillary tube. Hold the glass strip vertically in a clamp stand.

iii) Take full of water in a clean beaker. Hold a glass plate G in a clamp stand and attached three capillary tubes A, B, and C with wax. Put the capillary tubes is vertical and their ends deep well in the water. Water will raise in the tube make the capillary tube and the needle vertical. Raise the stand so that the head of the needle just touches the surface of water. Do not touch the surface of water with fingers.

iv) To set the traveling microscope:-
  a) Adjust the position of eyepiece so that the cross wire is clearly visible.
  b) Place the microscope with its horizontal traverse parallel to the plane of the glass plate.
  c) Adjust one of the leveling screws at the base of the microscope, so that its scale is vertical and the microscope tube is horizontal.
  d) Make the base and the axis of a traveling microscope horizontal by using a strip level. Also focus the cross wires of the microscope sharply.

v) Now bring the microscope in front of the needle and lover it cross wire is in the position B, symmetrically between the head of the needle and its image in water. The water rises along the needle as soon as its head touches the surface. It is difficult to focus the microscope on the head of the needle through the layer of water. The slow motion screw is worked so as to lower the dish containing water without disturbing the head of the needle, which becomes making. Microscope is now focused on the head of the needle and the reading of the vertical scale is noted.

vi) Adjust the height of the microscope such that its horizontal cross wire just touches the lower meniscus in capillary tube A and read the microscope scale. Take the difference of this reading and the reading in (v) above. Subtract this two reading from vertical scale to get the height (h). Repeat the experiment with two other capillary tube of different height rises in the tube.

vii) Now break the tube at the level of the meniscus with a file and hold it horizontally. By moving the microscope horizontally, make the vertical cross wire tangential to left side of the bore. Read the horizontal scale of the microscope. Shift the microscope horizontally until the vertical cross wire is tangential to the left side of he bore. Read the horizontal scale of the microscope. Shift the microscope horizontally until the vertical cross wire is tangential to the right side of the bore. Read the microscope again. Difference of these two readings gives the diameter of the bore. Similarly by the vertical movement of the microscope the diameter in the perpendicular position can be found. Take the mean of these two diameters and then find out the radius.

viii) Repeat the experiment with 2 (two) other capillary tubes of different bores.

ix) Water temperature is collected from the Laboratory.

Experimental Data:

Table 1: Data for the head of the needle

No. of obs.	Main scale reading M cm	Vernier scale divisions V	Vernier constant C cm	Vernier scale reading $V \times C$ cm	Total reading $R_1 = M + V \times C$ cm	Mean reading R_1 cm
1						
2						
3						
4						

Table 2: Reading for the meniscus in the tubes

Tube	No. of obs.	M.S.R. M cm	V.S. division V	Vernier constant C, cm	V.S.R $V \times C$ cm	Total reading $R_2 = M + V \times C$ cm	Mean R_2 cm	Height of the water meniscus $(R_2 - R_1)$ cm
A	1							$h_A = R_2 - R_1$
	2							
	3							
B	1							$h_B = R_2 - R_1$
	2							
	3							
C	1							$h_C = R_2 - R_1$
	2							
	3							

Table 3: Measurement of the radius, r of the tubes

Tube	Direction of obs.	Readings for the bore left or lower end				Readings for the bore right or upper end				Diameter $D = x_2 - x_1$ cm
		MSR M cm	VSD	VSR cm	Total X_1 cm	MSR M cm	VSD	VSR cm	Total X_2 cm	
A	Horizontal									$D_A =$
	Vertical									
B	Horizontal									$D_B =$
	Vertical									
C	Horizontal									$D_C =$
	Vertical									

Mean radius $r_A = \frac{D_A}{2}$, $r_B = \frac{D_B}{2}$, $r_C = \frac{D_C}{2}$

Table 4: Data for water temperature and density

Today's temperature of water, t = (Temperature data should be collected from the Lab.)

Density of water at this temperature, ρ = (Density of water should be collected from the chart)

Calculation:

$$T_A = \frac{1}{2}\rho g r_A\left(h_A + \frac{r_A}{3}\right) dynes/cm$$

$$T_B = \frac{1}{2}\rho g r_B\left(h_B + \frac{r_B}{3}\right) dynes/cm$$

$$T_C = \frac{1}{2}\rho g r_C\left(h_C + \frac{r_C}{3}\right) dynes/cm$$

$$T = \left(\frac{T_A + T_B + T_C}{3}\right) dynes/cm$$

Discussion:

i) The capillary tubes should be of uniform bore.
ii) Capillary tubes should be perfectly vertical otherwise reading will differ.
iii) The needle should be touching the water just above the surface.
iv) The diameter of the capillary tubes should be measured at the point where the liquid level

stands.

v) Water should rise freely in the capillary tube.

vi) River or tap water should be used and not distilled water. The surface of water should be free from grease. For this purpose the beaker should washed with acid before it is used for the experiment.

Oral Questions and their Answers:

Q1. Define surface tension. What is its units and dimension?

Ans. If a straight line of unit length is drawn in the liquid surface then the portion of the surface on opposite sides of the line tends to draw away from each other with a force. This force acts tangential to the surface and perpendicular to the line drawn. Its unit in C.G. S system is dyne/cm.

The dimension of surface tension $=MT^{-2}$

Q2. What is the angle of contact?

Ans. The angle between the two tangent planes with the liquid is called the angle of contact between liquid and solid.

Q3. Define cohesive forces?

Ans. Cohesive force is the force of attraction between two similar kinds of molecules and adhesive force is that between two dissimilar kinds of molecules.

Q4. What is the effect of temperature on surface tension?

Ans. Surface tension decreases with increase of temperature because due to the increase of temperature the density of water decreases so that surface tension will also be decreases.

Q5. What is critical temperature?

Ans. Critical temperature is the highest temperature at which a gas can be liquefied by pressure alone.

Q6. What surface tension does vanish?

Ans. Surface tension vanishes at the critical temperature.

Q7. What is the effect of electrification on surface tension?

Ans. Surface tension decreases when a liquid is electrified.

Q8. On what factors does the surface tension of a liquid depend?

Ans. i) On the nature of the liquid.
ii) On the nature of surface in contact and
iii) On the temperature of liquid, higher the temperatures, less the surface tension.

Q9. Should the top of the capillary tube be open or closed?

Ans. The top of capillary tube must be open.

Q10. Why don't you use distilled water instead of tap water?

Ans. During distillation process, vapor of water comes in contact with various tube joints having wax sealing and is thereby contaminated.

Q11. Why water rises and mercury drops in the tube?

Q12. What happened when a drop of water and mercury falls on the wooden surface? Why?

Ans. See the text book.

HEAT AND THERMODYNAMICS

Experiment 1

To Determine the Specific Heat of Liquid by the Method of Cooling

Theory:

The rate of loss of heat of a liquid is directly proportional to the temperature difference between the liquid and that of the surroundings.

$$\frac{-dQ}{dt}\alpha(\theta_2-\theta_1) \qquad (1)$$

Where θ_2 and θ_1 are the temperatures of liquid and surrounding respectively and $\frac{dQ}{dt}$ is the rate of heat loss. According to Newton's law of cooling, the rate of cooling of a body depends upon (i) difference of temperature between the body and that of the surrounding and (ii) the area of the surface exposed to the medium. Hence if equal volumes of different liquids heated to the same initial temperature θ_1 (say) are taken successively in the same or exactly similar colorimeters temperature suspended within an enclosure whose walls are maintained at a constant temperature θ_2. Their rates of cooling are equal and independent of the nature of the liquid. Since the thermal capacities of the liquid and water are different then the time taken by them to fall through the same range of temperature will be different.

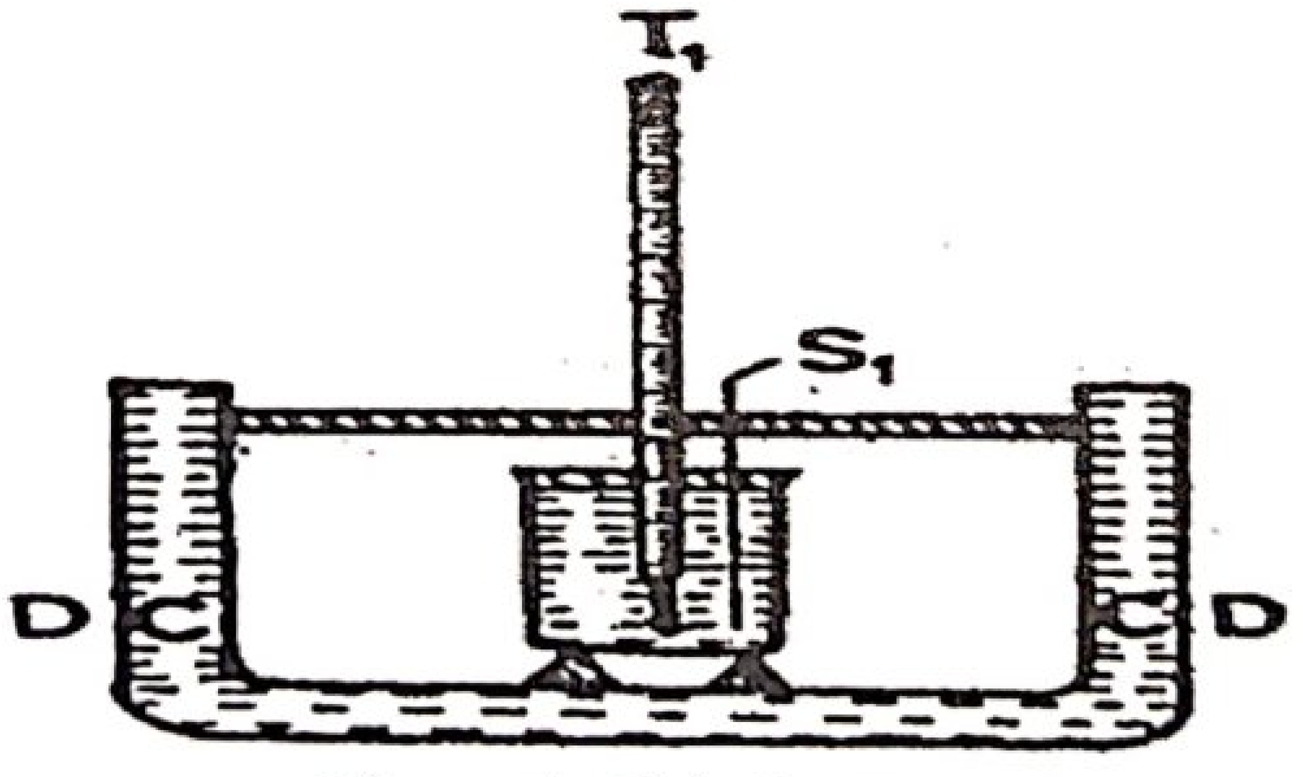


Figure 1: Calorimeter

Suppose,

M_l = mass of liquid
S_l = specific heat of liquid
M_w = mass of water
S_w = specific heat of water
M_c = mass of calorimeter

Suppose, if a mass M_l of liquid of specific heat s_l, takes t_1 seconds to cool from θ_1 to θ_2 and a mass M_w of water of specific heat S_w takes t_2 seconds to cool between the same ranges of temperature. If M_c and S_c are the mass and specific heat of the calorimeters then the rate of cooling for liquid and water are

$$\frac{(M_1S_1+M_cS_c)(\theta_1-\theta_2)}{t_1} \quad and \quad \frac{(M_wS_w+M_cS_c)(\theta_1-\theta)}{t_2}.$$

The rates of cooling in both the cases are equal

$$\text{So,}\frac{(M_1S_1+M_cS_c)}{t_1}=\frac{(M_wS_w+M_cS_c)}{t_2} \qquad (2)$$

Equating the equation, we get

$$S_1=\frac{1}{M_1}\left[t_1\frac{(M_wS_w+M_cS_c)}{t_2}-M_cS_c\right] \tag{3}$$

$$S_1=\frac{M_wS_wt_1+M_cS_c(t_1-t_2)}{M_1t_2} \tag{4}$$

Apparatus: Stop watch, Thermometer, Cylinder, Calorimeter, Sprit lamp and Beaker.

Procedure:

1. Heat 10cc kerosene in a beaker to about 75° C.
2. Pour the hot kerosene in a calorimeter.
3. Cover the calorimeter with their lids and insert the thermometers in them.
4. When the temperature of the kerosene is about 70° C, start the stopwatch and take the reading of the thermometer at intervals of 1 minute as the temperature falls from 70° C to 45°C (say) keeping the liquid gently stirred all time.
5. Repeat this procedure exactly for 100c.c. of water.
6. Plot the two cooling curves on the same graph paper taking temperature in the Y-axis and times in the X-axis. The cooling curve for oil will be found to be steeper than that for water. From the curves determine the time required for kerosene and for water to cool thought the same range of temperature. Then calculate the specific heat of kerosene using equation3.

Experimental Data:

Time temperature record: Temperature range 70° C to 45° C (Take the reading until temperature reached to 45°C)

No. of obs.	Time of cooling	Temp. of cooling for water °C	Temp. of cooling for Kerosene °C	No. of obs.	Time of cooling	Temp. of cooling for water °C	Temp. of cooling for Kerosene °C
1				19			
2				20			
3				21			
4				22			
5				23			
6				24			
7				25			
8				26			
9				27			
10				28			
11				29			
12				30			
13				31			
14				32			
15				33			
16				34			
17				35			
18				36			

Mass of the calorimeter with stirrer M_c=……gm (you will collect from the lab)

Specific heat of the material of the calorimeter S_c =… (you will collect from the lab)

Mass of the water M_w=……gm

Mass of the kerosene M_l=……gm

Specific heat of the water S_w=………

t_1=time taken by kerosene to cool from …to……=………… minute =……….sec.

t_2=time taken by water to cool from……to………=…………..minute =……….sec.

Discussion:

1. Evaporation is a chief source of error for liquid. To avoid this evaporation calorimeter should be provided with a lid having holes for thermometer and a stirrer.
2. The temperature of water and liquid in the calorimeter should not be raised above 70° C as in that case evaporation generally takes place from its surface.
3. Liquid should not be heated close to its boiling point.
4. The volume of the liquid and water should be same.
5. The maximum temperature of water and kerosene should be the same and about 30° C above the room temperature.
6. Calorimeter should not touch the walls or the bottom of the vessel and should be suspended by a non-conductor.

Oral Question and their Answers:

Q1. State Newton's law of cooling.

Ans. See the text

Q2. Does Newton's law of cooling hold well when the temperature difference between the body and its surroundings is very large?

Ans. No. it is strictly true only for a small difference of temperature. This radiation law holds true when the temperature difference by the body and that of its surroundings is not more than 30^0 C. It is better when the temperature difference only 10° C.

Q3. Is it an accurate method?

Ans. No, it is a quick method. The law of cooling does not hold strictly for large temperature difference.

Q4. What is the principal process by which heat is lost from the calorimeter in the arrangement you have made?

Ans. Radiation is the principal process by which heat is lost from the Calorimeter.

Q5. Will the experiment succeed if we keep the calorimeter open and why?

Ans. In this case radiation loss will increase due to difference of temperature between the liquid and the surroundings.

Q6. Why is it necessary to use the same volume of the two liquids?

Ans. In this way the surface area, from which radiation occurs, is kept equal in both case.

Q7. Can we heat the liquids to any temperature we like?

Ans. No, temperature must be rises less than boiling point of the liquids.

Q8. Should the liquids have the same volume or the same masses?

Ans. The volume of liquids taken in calorimeter must be same.

Q9. Would you prefer a calorimeter well-polished or painted black?

Ans. We prefer a calorimeter should have thin walls and their outer surfaces should be painted black.

Q10. Does Newton's law of cooling hold for solids also?

Ans. Newton's law of cooling holds only for liquid not for solids.

Q11. What are the factors on which the radiation of heat from a hot body depends?

Ans. See the text

Q12. What is the chief source of error and how to avoid it?

Ans. The chief source of error is due to evaporation of the liquid. To avoid this, the calorimeter should be provided with a lid having hole for thermometer and a stirrer. When necessary a rotary stirrer should be employed for up and down stirrer would promote evaporation.

Experiment 2

To Determine the Co-efficient of Thermal Conductivity of a Bad Conductor by Lees and Charlton's Method

Theory:

The thermal conductivity of a bad conductor like rubber, glass, leather, cardboard, ebonite etc. can be determined by Less and Chorlton's method. A brass disc A of about 10 cm in diameter is supported by means of strings from a large ring of retort stand. The experimental material in the form of a thin circular slab S of uniform thickness and having the same diameter as A is placed on it. A steam chamber C is placed on the slab S. The bottom part B of the steam chamber C is a thick metal plate having the same surface area as that of A. The surface of B and A are nickel plated to obtain uniform and good emissive.

On passing steam through a steady state reached soon on B. After sometimes a steady state is reached on A when the rate of flow of heat through S equal to the heat lost from A by radiation and convection. So the quantity of heat conducted per second through the poor-conducting slab S is

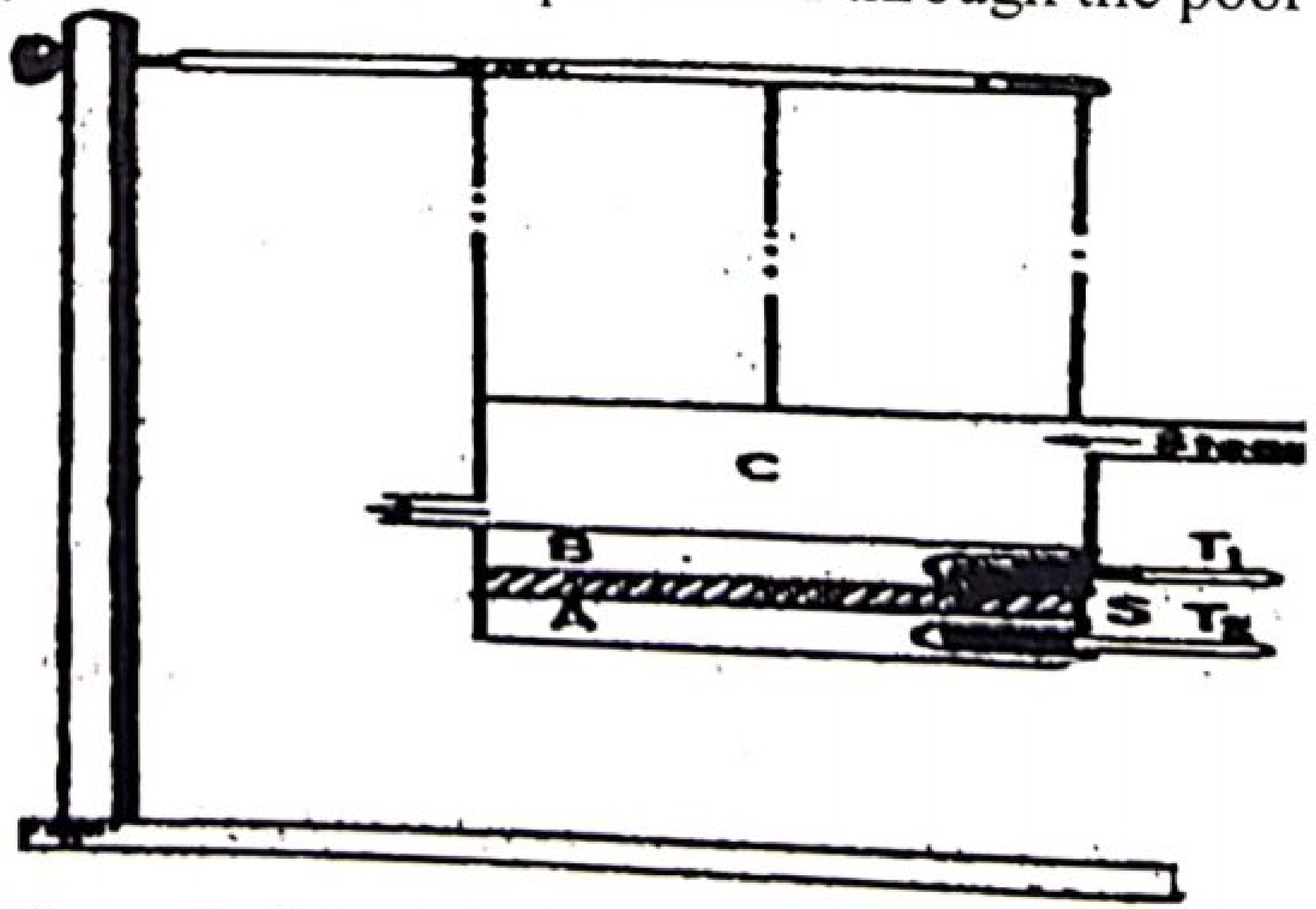


Figure 1: Determination of thermal conductivity

$$Q = \frac{KA(\theta_1 - \theta_2)}{d} \tag{1}$$

where θ_1 & θ_2 are the temperature of B & A in the steady state respectively?

A=Area of cross-section of the slab S
K=Thermal conductivity of the slab S
D=thickness of the slab

If M and S are the mass and specific heat of the metal disc A, then the rate of cooling at of A is equal to

$$Q = MS\frac{d\theta}{dt} \tag{2}$$

Where $\frac{d\theta}{dt}$ is the rate of fall of temperature of A. Since the heat loss in both cases is equal then from equation(1) and (2), we get

$$\frac{KA(\theta_1-\theta_2)}{d} = MS\frac{d\theta}{dt} \quad \Rightarrow K = \frac{MS\frac{d\theta}{dt}.d}{A(\theta_1-\theta_2)} \tag{3}$$

Apparatus: Lees and Charlton's disc apparatus, Circular disc of a bad conductor, Two thermometers, Slide calipers, Screw gauge, Burner and Heater.

Procedure:

1. Measure the diameter of the disc S with slide calipers. By using the screw-gauge determine the thickness s of the disc S.
2. Arrange the apparatus as shown in Figure 1 and place the thermometer T_1 and T_2 in respective position.
3. Now, pass the steam from the inlet of the cylindrical vessel and note temperature of θ_1 and θ_2 of B and A respectively at the interval of 5 minutes until they remain steady at least three consecutive interval i.e. for 15 minutes. Note θ_1 and θ_2 from thermometer T_1 and T_2 .
4. Remove the cylindrical vessel B and C. Heat the disc A taking S top of A by moving burner under it till its temperature rises about 10^0 C (θ_2+10^0C) above the steady temperature θ_2. Now remove the burner and note the temperature at the interval of half minute until the temperature falls by about 10^0 C from $\theta_2(\theta_2-10^0C)$.
5. Plot a graph as taking time of cooling (t) as abscissas and temperature (θ) as ordinate. Draw a tangent at a point at which the value of the ordinate is θ_2.

Table 1: Diameter of the bad conductor disc S

No. of obs.	Main scale reading M cm	Vernier scale divisions V	Vernier constant C cm	Vernier scale reading $V\times C$ cm	Total reading $M+V\times C$ cm	Mean diameter d cm
1						
2						
3						

Table 2: Thickness of the bad conductor disc S

No. of obs.	Main scale reading L cm	Circular scale reading S	Least Count C cm	Value of circular scale division $(C\times S)$ cm	Total reading $L+S\times C$ cm	Mean thickness cm
1						
2						
3						
4						

Table 3: Time-temperature records of A and B

Time in Minutes	0	5	10	15	20	25	30	35	40	etc.
θ_1										
θ_2										

Table 4: Time-temperature record of A during its cooling (Take reading for maximum to minimum temperature difference 20°C)

Time in minutes	0	0.5	1.0	1.5	2	2.5	3	3.5	4	4.5	5	5.5	etc.
Temperature °C													

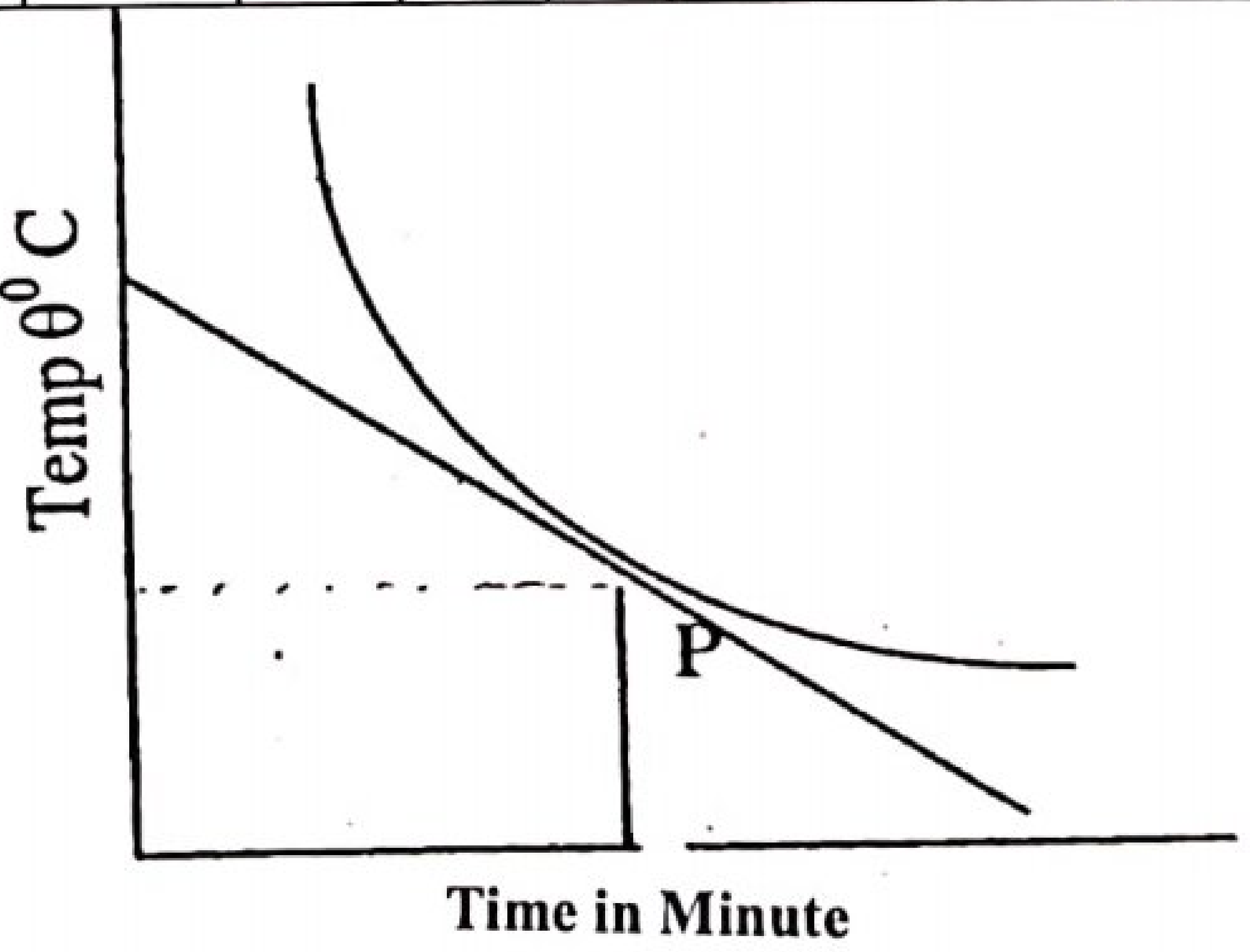


Figure 2: Time-Temperature curve (Cooling curve)

The slope of this tangent gives the rate of cooling,

$$\frac{d\theta}{dt}=\frac{PQ}{QL} \qquad (4)$$

Experimental Results:

Mass of the lower disc C, M=.............gm (Given)
Specific heat of the material of lower disc C, S = ...(Given)
Instrumental error x =± ....cm

Discussion:

1. The temperature θ_1 and θ_2 at A and B respectively should be noted when they remain .

steady at least 10-15 minutes.

2. Thermometer should be placed close to the face of the disc S.
3. The diameter of the disc should be measured at a number of places and at every place in two mutually perpendicular directions.
4. Diameter of the disc S should be made equal to those of B and C.
5. The thickness of the disc S should be measured at a number of points on the surface.
6. During cooling the temperature of the lower disc A should be noted every half-minute of more frequently if the rate of cooling be very rapid.
7. PQ must be measured in ^{0}C and QL in Sec.

Oral Questions and their Answers:

Q1. Define co-efficient of thermal conductivity

Ans. The co-efficient of thermal conductivity of a substance is the quantity of heat flows in one second through the opposite faces of the block of a material having area of each face 1 cm^2 and the distance between the faces 1 cm. and the opposite face are maintained at a temperature difference of 1°C.

Q2. Is Lee's method applied in case of (i) a conductor and (ii) a liquid?

Ans. (i) No, it can't be applied in case of a conductor.

(ii) Yes provided the disc A is replaced by a thin walled flat-end receptacle containing the liquid.

Q3. Distinguish between steady and variable states.

Ans. Steady state: This state when then there is no absorption of heat by the bar and no temperature increase of any part of the bar is called the steady state.

Variable state: The state during which the temperature of each portion of the bar is changing is known as the variable state.

Q4. Does the thermal conductivity depend on temperature?

Ans. Yes, it decreases with rise of temperature.

Q5. Why should be experimental disc be thin in Lee's and Chorlton's method?

Ans. In measuring the conductivity of such a poor conductor one must remember that a thin disc of the material must be used. If the disc is thin then the surrounding of the disc should be thin and heat lost due to radiation would be minimal.

Q6. What is temperature gradient and what is its mathematical expression?

Ans. The change of temperature per unit distance is called temperature gradient. The mathematical expression of temperature gradient is $(d\theta/dx)$.

Q7. Does the value of thermal conductivity depend on the dimension of the substance?

Ans. No, it depends only on the material of the substance.

Q8. Why the two thermometers should be placed close to the face of the disc of the specimen?

Ans. The steady state temperatures should be recorded only when the two thermometers remain constant.

SOUND

Experiment 1

To Determine the Frequency of a Tuning Fork by Melde's Experiment

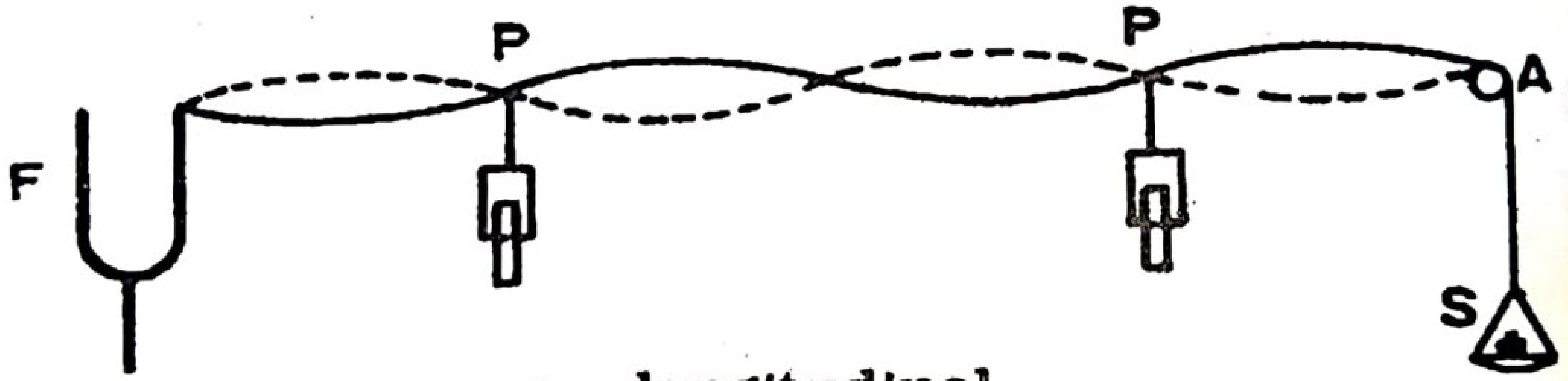
Theory:

A string can be set in to vibrations by means of tuning fork, thereby producing stationary waves due to reflection of waves at the pulley. The ends of the string are fixed to the prong of the tuning fork and the position where it touches the pulley are nodes.

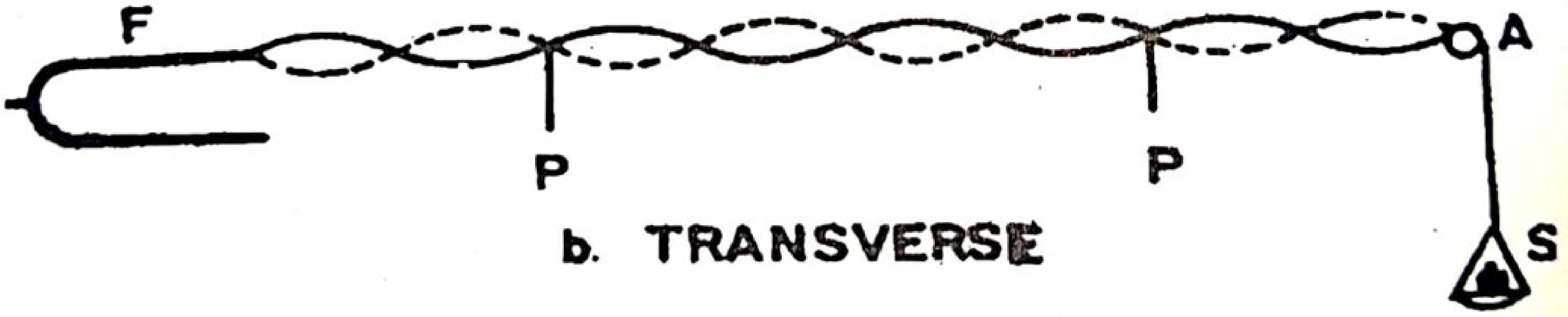
The motion of the prongs of the fork, which sets the string in resonant vibration, may be in two different directions.

i) Transverse position: The fork is struck with its place of vibration perpendicular to length of the string.

ii) Longitudinal position: The fork is struck with its plane of vibration parallel to length of the string.



a. longitudinal



b. TRANSVERSE

If V were the velocity of a disturbance which travels along the vibrating string, which is under a Tension T and mass per unit length m then

$$V=\sqrt{\frac{T}{m}} \qquad (1)$$

If n be the frequency of the mode of vibration of the string and λ be the corresponding wave-length, then V= nλ

$$n=\frac{1}{\lambda}\sqrt{\frac{T}{m}} \qquad (2)$$

If the thread of length 1 vibrates into one loop, then $\lambda = 21$

$$n=\frac{1}{21}\sqrt{\frac{T}{m}} \qquad (3)$$

Therefore, for transverse position, the time during which the tuning fork completes one vibration, the string also completes one vibration. The frequency of the fork is

$$N = n = \frac{1}{\lambda}\sqrt{\frac{T}{m}} = \frac{1}{21}\sqrt{\frac{T}{m}} = \sqrt{\frac{T}{4l^2 m}} = \sqrt{\frac{1}{4m}\left(\frac{T}{l^2}\right)} \qquad (4)$$

In case of longitudinal vibration the time during which the tuning fork completes one vibration the string completes half a vibration. Hence the frequency of the thread is half that of the tuning fork. Frequency of fork = 2 × frequency of the string.

$$N = 2n = 2 \times \frac{1}{21}\sqrt{\frac{T}{m}} = 2\sqrt{\frac{1}{4m}\left(\frac{T}{l^2}\right)} \qquad (5)$$

Apparatus: Tuning fork, thread, a stand with clamp, pulley, meter scale, weight box etc.

Procedure:

1. The fork is kept in either transverse of longitudinal position. Weight of the scale plan is taken from the laboratory.
2. Place some small weight in the pan attached to the end of the string passing over the pulley.
3. The fork is struck lightly by rubber-padded hammer/electrically maintained equipment. Adjust the position of the pulley so that the string is set into reasonable vibration and well-defined loops are obtained.
4. Measure the length of (say 3, 4, 5, 6 or 7) loops formed in the string. If L is the distance in which 5 loops are formed. Then distance between two consecutive nodes. $l = \frac{L}{5}$
5. Particular loops, which are given by the sum of the weight of the scale pan and weight of the scale pan and weights, put on it.
   Note down the weights placed in the pan and calculate the tension.
   $$T = \text{weight placed in the pan} \times g = (W + W_1) \times g \text{ dynes}$$
6. The whole procedure is repeated with the other position of the fork.

Calculate the frequency (N) of the given fork with the help of equation (iv) and equation

Table 1: Calculation of frequency of tuning fork at longitudinal position

No. of obs.	Load on the scale pan w' gm	Tension $T=(w+w')g$ dynes	No. of loops p	Length of the thread L (cm)	Length of each loop $l = L/p$ (cm)	$\frac{T}{l^2}=$ Constant $dynes/cm$	Frequency of the string $n=\sqrt{\frac{1}{4m}\left(\frac{T}{l^2}\right)}$ vib/sec	Frequency of fork $N=2n$ vib/sec
1								
2								
3								
4								

Table 2: Calculation of frequency of tuning fork at transverse position

No. of obs.	Load on the scale pan W' gm	Tension $T=(w+w')g$ dynes	No. of loops p	Length of the thread L, cm	Length of each loop $l = L/p$ (cm)	$\frac{T}{l^2}=$ Constant $dynes/cm^2$	Frequency of the string $n=\sqrt{\frac{1}{4m}\left(\frac{T}{l^2}\right)}$ vib/sec	Frequency of fork $N=n$ vib/sec
1								
2								
3								
4								

Calculations:

A. Mass of the pan W= ………………..gm

B. Length of the thread L = …………………cm

Mass of the thread M=…………………mg

Mass per unit length of the thread, m= M/L = ……..gm/cm

Discussion:

i. The thread should be uniform and in extensible.

ii. The weight of the scale pan should always be added to the loads placed on it.

iii. The fork should be vibrated each time by only a single stroke of the hammer and not by successive strokes.

iv. Well-defined loops would be obtained by adjusting the tension with milligram weights.

v. The total number of loops may be increased or decreased by decreasing of increasing the load on the scale pan, when the length of the string is fixed.

Oral questions and their Answers:

Q1. What is a stationary wave?

Ans. The effect of superposition of two sets of identical progressive waves (waves having the same amplitude and time period) but traveling in opposite direction with the same velocity. This is a case, which very often occurs with stationary sound waves.

Q2. How are the stationary waves formed in Melde's Experiment?

Ans. Stationary waves are produced due to the superposition of the direct waves sent by the tuning fork and same waves reflect from the pulley.

Q3. How the transverse arrangements differ from a longitudinal arrangement?

Ans. In case of longitudinal mode of vibration the fork and the string vibrate in the same direction but in case of transverse mode of vibration the tuning fork and the string are set into perpendicular direction.

Q4. What are the modes in which a string can vibrate?

Ans. There are two modes in which tuning fork vibrate. The modes are longitudinal and transverse.

Q5. How the tension will vary if the number of loops is to keep the same in the two arrangements?

Ans. Tension in the longitudinal arrangement will be one-fourth of that in the transverse arrangement?

Q6. Why the length of the string between pulley and the scale pan should be kept short?

Ans. Otherwise the approximate mass of this portion the string will increase the tension of the string.

Q7. Can you perform your experiment with a thick wire?

Ans. The rigidity of the wire in addition to its tension will have controlling force and the simple formula employed not hold well.

Q8. What are nods and antinodes?

Ans. [See figure]. N are the nodes which are permanently at rest while A are the antinodes at which the medium swings to and sown the maximum extent. At the nodes displacement = 0, velocity = 0 and the change of density is maximum and density be = 0.

Q9. How do you know that resonance has occurred between the fork and the string?

Ans. When the amplitude of vibration of the antinodes is greatest we know that the desired resonance has occurred.

Q10. Why the loops in the central part of the thread should be counted for measurements?

Ans. The loops in the central part of the thread should be counted for measurements. The nodes at the tip of the prong and at the pulley should be neglected as these have some motion.

Light

Experiment 1

To Determine the Refractive Index of a Liquid by using a Lens and a Plane Mirror

Theory:

If a double convex lens is placed on a few drops of liquid above the plane mirror, the liquid film between the lens and the plane mirror forms a plano-concave liquid lens. The curved surface of this liquid lens has the same radius of curvature as the surface of the lens with which it is in contact. If F be the focal length of the combination of two lenses one of convex lens and the other of liquid, which behaves as a convergent lens.

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2} \qquad (1)$$

Where f_1 and f_2 are the focal lengths of the convex lens and the liquid lens respectively
Correcting for signs of F and f_1 which are both negative

$$\frac{1}{f_2}=\frac{1}{f_1}-\frac{1}{F}=\frac{F-f_1}{Ff_1}\text{, therefore } f_2=\frac{f_1F}{F-f_1} \qquad (2)$$

Determining F and f_1 experimentally and calculate f_2 from equation 2. Again the focal length f_2 of the Plano-concave liquid lens is given by

$$\frac{1}{f_2}=(\mu-1)\left(\frac{1}{r}-\frac{1}{r_1}\right)$$

$$\Rightarrow\frac{1}{f_2}=(\mu-1)\left(\frac{1}{r}\right)\ [r_1=\infty]$$

$$\therefore \mu=1+\frac{r}{f_2} \qquad (3)$$

Where r is the radius of curvature of the lower surface of the convex lens and μ is the refractive index of the liquid.

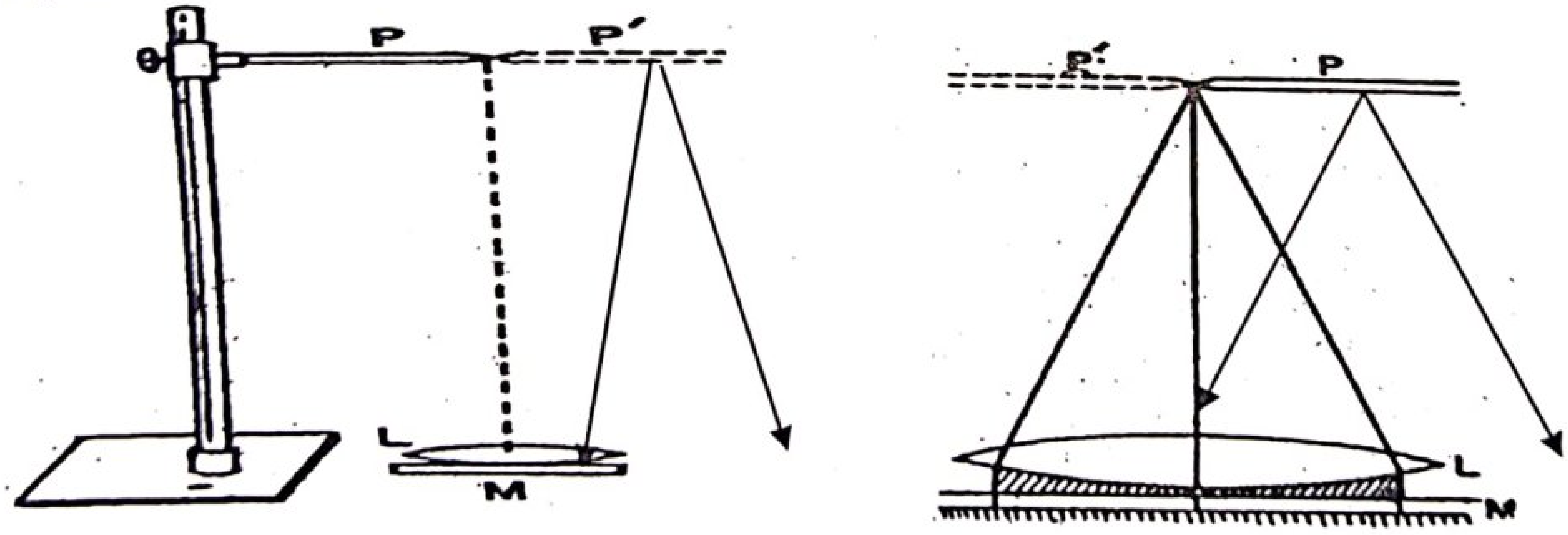


Figure 1: Convex lens is placed over the plane mirror with and without liquid

Apparatus: A convex lens, plane mirror, pin with its tip painted white, spherometer, slide calipers, stand and some experimental liquid.

Procedure:

1. The thickness of the convex lens is measured at its centre by slide calipers. Measure the radius of curvature of that surface of the lens which was in contact with the liquid. The radius of curvature r is given by

$$r = \frac{D^2}{6h} + \frac{h}{2}$$

Where D is the distance between the outer legs of the spherometer and h is the elevation of the central leg over the plane on which the outer leg stand when the tip of the former just touches the lens surface.

2. The convex lens L is then placed on a plane mirror M. A pin P is clamped horizontally on a suitable stand of adjustable height, so that the tip of the pin is along the axis of the lens. The position of the pin P is adjusted such that a real, inverted image is visible. Any parallax between the image of the tip and the tip itself is avoided.
3. The distance d_1 between the tip of the pin and the upper surface of the lens is measured. When half of the thickness is added with this and it gives the focal length of the convex lens. Repeat the operation d_1 for three or four different settings and take the mean value of d_1.

$$f_1 = d_1 + \frac{t}{3}$$

4. After determining the focal length of the convex lens, the lens removes from the mirror and pours a few drops of the experimental liquid on the surface of the mirror. The lens is again placed over the liquid. This time the pin P and the image coincide at P'. The distance between the tip of the pin and the upper surface of the lens is measured. The combination of the liquid lens and the convex lens behaves as a convergent lens. Repeat the operation d_2 for three or four different setting and take the mean value d_2.

Experimental Data:

A) Determination of the radius of curvature of the surface of the lens by spherometer

Pitch of the micrometer screw p= ....mm =............cm

No. of divisions in the circular scale n = ...

Least count of the instrument p/n =.................................... cm

Measurement of D (i) ....cm, (ii)............cm and (iii)..............cm

Radius of curvature $r = \frac{D^2}{6h} + \frac{h}{2}$

Table 1: Thickness of the lens is measured at its center by slide calipers

No. of obs.	Reading			Mean reading in cm	Instrumental Error in cm	Corrected reading in cm	Mean thickness t cm
	MSR S in cm	VSR V in cm	Total (S+V)				
1							
2							
3							

Table 2: Data for measurement of height of the lens h

Reading on	No. of obs.	Linear scale reading L cm	Circular scale Division C	Least count V cm	Instrumental Error N cm	Total (L+ $C \times V) \pm N$ cm	Mean cm	h=S-B cm
Base plate B	1							
	2							
	3							
Lens surface S	1							
	2							
	3							

Table 3: Determination of the focal length of liquid lens

No. of obs.	Distance between pin and the face of the lens without liquid h_1 cm	Focal length of the convex lens $f_1=h_1+t/3$ cm	Mean f_1 cm	Distance between pin and top of the lens surface with liquid h_2 cm	Focal length o the combination $F=h_2+t/3$ cm	Mean F cm	Focal length of the liquid lens $f_2=\frac{Ff_1}{F-f_1}$ cm
1							
2							
3							

Calculation: Refractive index of the liquid $\mu=1+\frac{r}{f_2}$

Discussions:

1. The pin should be moved along the axis of the lens so that refraction may take place through the center of the lens by which spherical and chromatic aberrations may be avoided.
2. If the pin placed within the principal focus of the lens a virtual correct image will be observed. The pin has to be moved further away from the lens till the image seen in inverted.
3. The point of coincidence is found by strictly avoiding parallax.

Oral Questions and Answer:

Q1. What is the nature of the liquid lens?

Ans. It is a Plano-concave lens.

Q2. Is the focal length of the liquid lens greater or smaller than that of the convex lens?

Ans. Greater, otherwise the combination cannot behave as a convex lens having the first principal focus on the positive side.

Q3. Can the refractive index of any value be measured by this method?

Ans. No, when the refractive index of the liquid is such that the focal lengths of both lenses are equal, the method fails. The maximum refractive index of liquid is

$\mu=1+\frac{r}{f_2}$ and then $\mu=1+\frac{r}{r}=2$ (for $f_2=r$)

Q4. Can you find the refractive index of the given liquid without using a spherometer?

Ans. Yes, by repeating the experiment with liquid of known refractive index (μ'), the focal length f_2 of the liquid concave lens is found out.

$\mu'=1+\frac{r}{f_2}$, therefore $r=(\mu'-1)f_2$

Hence the refractive index of the given liquid is given by

$$\mu=1+(\mu'-1)\frac{f_2'}{f_2} \quad \therefore \frac{\mu-1}{\mu'-1}=\frac{f_2'}{f_2}$$

Q5. What is parallax error and how to avoid it?

Ans. When the two objects are not coincident then with the movement of the eye, there will be a relative displacement between the two objects. This is parallax. When there is no relative displacement between the two objects with the movement of eye, then there will be no parallax.

Q6. Can you perform this experiment by a concave lens?

Ans. No, because concave lens cannot produce any real image.

Experiment 2

To determine the focal length and hence the power of a convex lens by displacement method with the help of an optical bench

Theory:

If the distance between an object and a screen were greater than four times the focal length of a given convex lens, then there will be two different positions of the lens for which an equally sharp image is obtained. L_1 and L_2, two positions of the lens for which an equally sharp image of the object can be formed on the screen. Let the points A, P, L_1 and L_2 in Figure 1 represents the position of the object, the image and the two different positions of the lens respectively.

Let the distance AP = d and L_1L_2 =x

$$AP=AL_1+L_1P= d = u+(-v) = u-v \tag{1}$$

$$L_1L_2=x= L_1P-L_2P = (-v)-u = -(u+v) \tag{2}$$

$$(AP)^2-(L_1L_2)^2 = d^2-x^2 = (u-v)^2-(u+v)^2$$

$$= u^2-2uv+v^2-u^2-2uv-v^2 = -4uv$$

$$\therefore uv = -\frac{d^2-X^2}{4} \tag{3}$$

Again, for convex lens:

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \therefore f=\frac{uv}{u-v} \text{ or } f=-\frac{d^2-X^2}{4d} \tag{4}$$

Or $\quad \frac{1}{d-u}-\frac{1}{u}=\frac{1}{f}$ (since $u+v=d$)

Applying the sign convention, u is -ve.

Or $\quad \frac{1}{d-u}+\frac{1}{u}=\frac{1}{f}$

$$u^2-ud+df=0$$

This is quadratic equation. We have two values of u corresponding to the two positions of the lens. These are

$u_1 = \frac{d}{2} - \sqrt{\frac{d^2-4df}{2}}$ position L_1 of the lens

and $\quad u_2 = \frac{d}{2} + \sqrt{\frac{d^2-4df}{2}}$ position L_2 of the lens

Then, $x = L_1 \sim L_2 = u_1 \sim u_2 = \pm\sqrt{d^2-4df}$

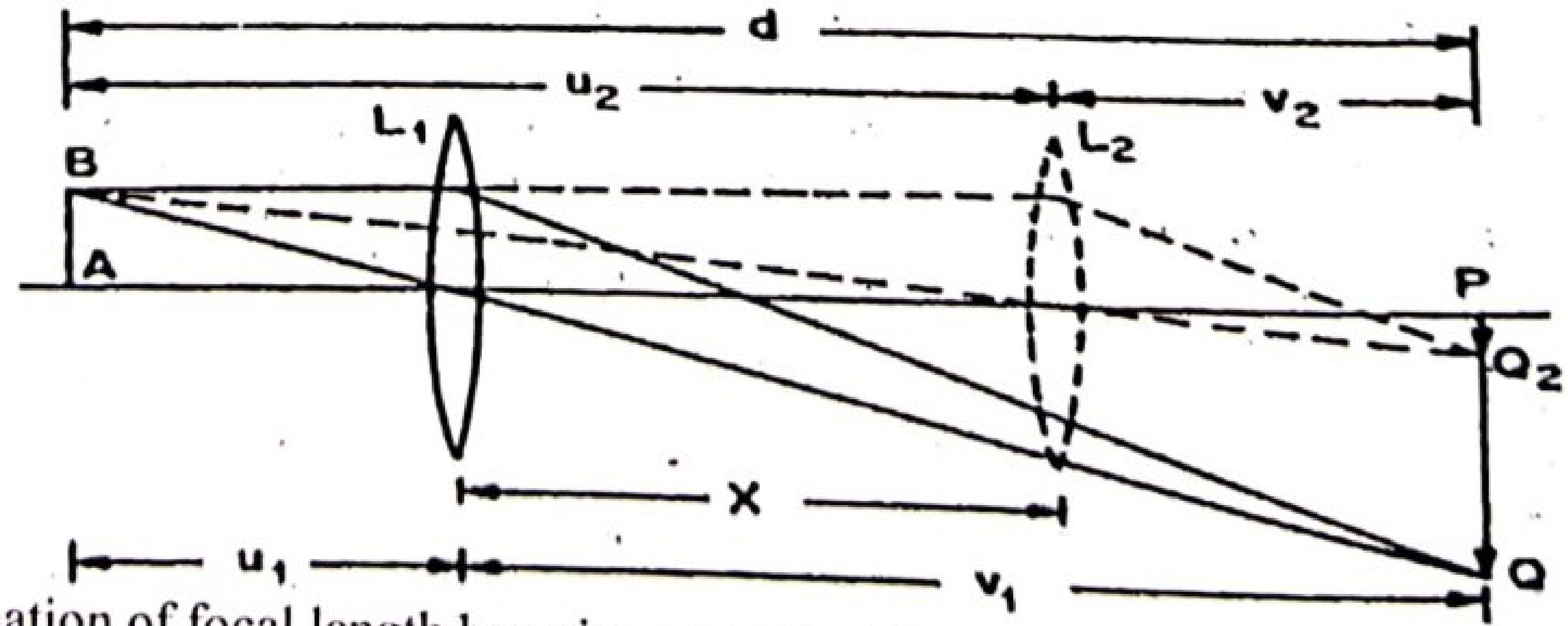


Figure 1: Determination of focal length by using an optical bench

or $\quad x^2 = d^2-4df \quad$ or $\quad f=\frac{d^2-x^2}{4d}$

Where d is the distance between the object and the image and $x$is the distance between two positions of the lens L_1 and L_2.

The power of the lens $P = \frac{100}{f(in \quad cm)} Diopters$

Apparatus: Optical bench, a convex lens, illuminated object and a translucent screen etc.

Procedure:

1. The focal length of the supplied lens is roughly estimated by holding in front of a distant lamp and obtaining a sharply focused image on a piece of paper. The distance between the lens and the paper given the approximate focal length.
2. The object (which may be fixed on the circular aperture of a screen, illuminated by a light source) and the image screen on their respective stands at a distance somewhat greater (by about 5cm) then four times of the focal length and their heights are adjusted such that the axis of the lens is parallel to the bench.
3. The convex lens is then gradually moved away for the object till a real, inverted and magnified image of the object is sharply focused on the screen. The position L_1 of the lens is recorded. Repeat this operation at least three times. The mean of these three readings gives the position L_1.
4. Now move the convex lens further away from the object, till you obtain another sharply defined real, inverted but reduced image on the screen. Note the position L_2 of the lens. Repeat the operation at least three times. The mean of which given the position L_2 of the lens.
5. Note down the position of the object and image screen, the difference of which gives the apparent distance $d_1$between the object and screen.
6. Determine the index correction for the object distance (between object and the image screen) is given by$(l - d)$. In order to gets the true distance$\lambda = (l - d)$ is to be algebraically added to the apparent distance. Then correct distance $d=d_1+ \lambda$ between the object and the image screen. The distance L_2-L_1= x, x is the displacement of the convex lens which is free from any index correction.
7. The whole experiment is repeated at least four times by increasing the distance d between object and the image screen in steps of 4 to 5 cm.
8. From the noted values of d and x, we can calculate f for each set of data. Now from the mean value of f we will determine the power P of the given convex lens.

Experimental data:

Table 1: Index correction (λ) for d

Length of the index rod in cm (l)	Difference of both scale readings in cm when the two ends of index rod touch the object and the screen (d)	Index correction $\lambda = (l - d)$ cm

Table 2: Reading for d and x

No. of obs.	Position of				Displacement of Lens $x = L_2 - L_1 (cm)$	Apparent distance between object and image $d^{/} = A - P$	Corrected distance between object and imaged $= d^{/} + \lambda$
	Object (A)	Image (P)	Lens at				
			L_1	L_2			
1.							
2.							
3.							
4.							
5.							

Table 3: Table for calculation of focal length (f)

No. of obs.	Lens displacement x in cm from Table 2	Corrected object distance d in cm from Table 2	Focal length $f = \frac{d^2-x^2}{4d}$ cm	Mean focal length f cm	Power $P = \frac{100}{f}$ Diopters
1					
2					
3					

Calculations:

$$f = \frac{d^2 - x^2}{4d} = \text{..........................}cm$$

Mean focal length $$f = \frac{f_1 + f_2 + f_3 + f_4 + \text{..........} + f_n}{n}\ cm$$

$$P = \frac{100}{f(in\ cm)}\ \text{Diopters}$$

Discussions:

i. Experiments will be made with a series of values of d and is true only when d>4f since the value of x diminishes with that of d=0 when d=4f numerically. On the other hand, d should not be very large since the diminished image could not be detected. The best way is to keep the values of d between 4f and 5f.

ii. The value of d should be changed by 4 to 5 cm. as slight change on the value of d causes a great change in the value of x.

iii. Proportional error of focal length has minimum if the displacement x be small and hence d should be adjusted accordingly.

iv. This method involves the determination of only one index error. Also, no determination of the thickness of the lens is involved.

Oral question and Answer:

Q1. Why do you keep the distance between the object and the screen greater than 4f?

Ans. For getting two images the distance between the object and the screen should require greater than 4f? Otherwise two images cannot be obtained.

Q2. What is the minimum distance between object and its real image formed by a convex lens?

Ans. The minimum distance between object and its real image is equal to 4f. If the distance between object and image is less than 4f, two images can't be formed. Then, displacement method will not be used for the determination of focal length of lens.

Q3. Is it advisable to make d large?

Ans. No, because the diminished image will be very small, and its focused condition cannot be traced.

Q4. Why the index correction for x is not necessary?

Ans. For the displacement of the lens must be equal to the displacement of the index mark of the lens stand.

Q5. What is the advantage of this method?

Ans. No index error for x is necessary. Thickness of the lens is not required.

Q6. Can the size of the object obtain by measuring the sizes of the two images?

Ans. Yes, if I_1 and I_2 are the sizes of the two images, then the size of the objects is expressed as O= $\sqrt{I_1 I_2}$

Q7. How to text a lens whether it is a concave convex or mirror?

Ans. If the lens to be placed very close to a painted paper, then if the image is
i) Magnified, the lens is convex.
ii) Diminished, the lens is concave.
iii) Equal to that of object, it is mirror.

Q8. Why one image is magnified while the other diminished?

Ans.
$$magnification = \frac{image\ dis\tan ce}{object\ dis\tan ce}$$

When the lens is nearer to the object image distance is greater and hence the image is magnified, when lens is nearer to the screen, the image distance is small and object distance is greater and the observed image is diminished.

Q9. By employing your data can you find 'f' graphically?

Ans. The final equation can be written as $x^2/d=d+4f$. If a graph is plotted with x^2/d as ordinate and d as abscissa, and straight line will be obtained and its intercept on the x-axis i.e. $y=x^2/d=o$ will give the value of 4f numerically.

Q10. Under what condition a real magnified or a diminished image be formed?

Ans. When the focus and 2f from the object then the image will real and magnified. But if the object is placed between 2f and infinity the image will be real and diminished.

Q11. What is index rod?

Ans. It is a rod mounted on a stand with pointed ends.

Q12. Why index correction is necessary?

Ans. In optical benches the readings are usually taken on scale at the base end. The distance between two objects on the principal axes may not be the same with the distance of index at their base on the bench scale.

Experiment 3

To Determine the Refractive Index of the Material of a Prism by using a Spectrometer

Theory:

If a narrow parallel beam of light from the collimator is allowed to fall on the edge of the prism (Figures 1 and 2), it is partly reflected from the face AB and partly from the face AC. If the telescope is placed with its axis parallel to $Q'R'$ then an image of the slit will be seen in it. If the telescope is rotated so that its axis lies parallel to QR the image of the slit will again be seen on the other side. The angle of the prism is equal to half of the angle through which the telescope is rotated.

As $P'Q'$ is the incident ray and $Q'R'$ the reflected ray then

$$\langle P'Q'A = \langle R'Q'C = \langle AQ'D$$

$$\langle Q'AD = \langle AQ'D = A/2$$

$$\langle Q'DO = \langle Q'AD + \langle AQ'D = A/2 + A/2 = A$$

Similarly, $\langle QDO = A$

Hence $\langle QDO' = \langle QDO + \langle Q'DO = 2A$

$$\therefore A = \frac{1}{2}\langle QDO' = \frac{1}{2}\langle RDR'$$

This is the angle of the prism.

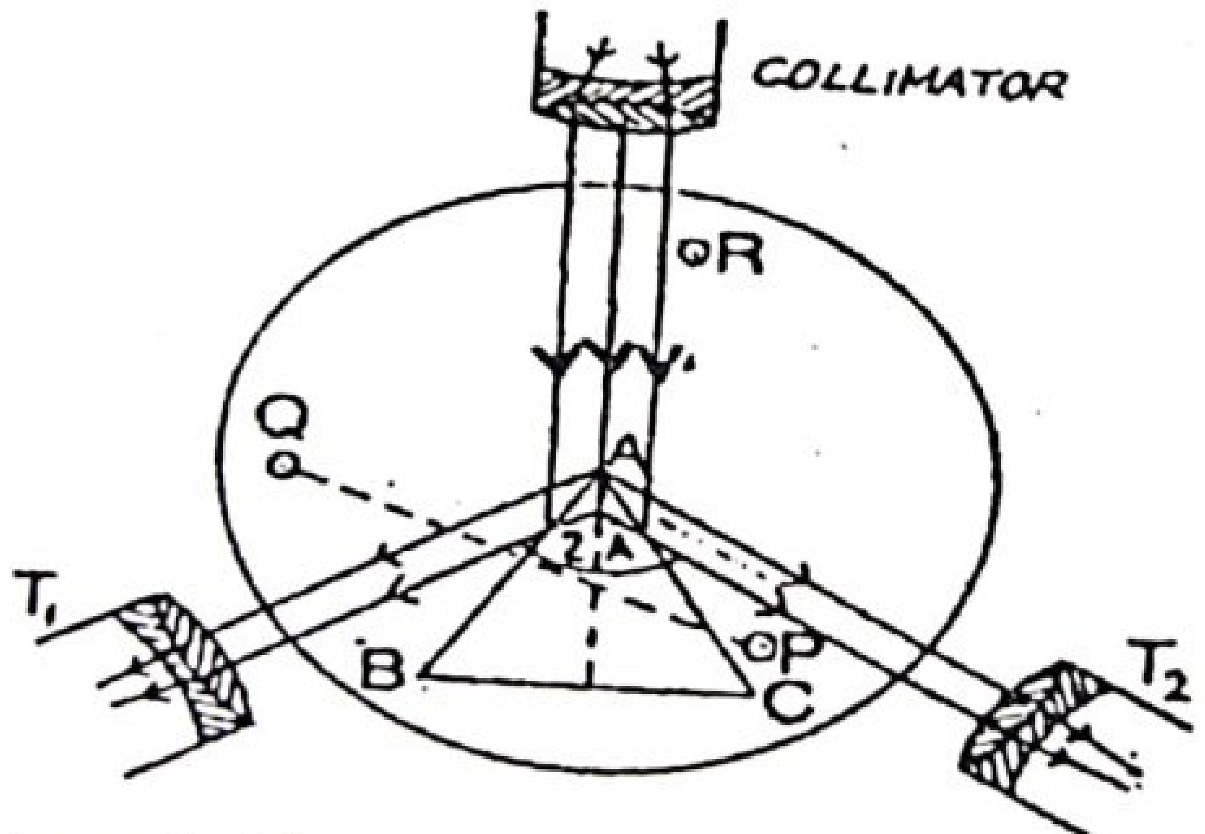


Figure 1: Placement of Telescope for measuring Prism Angle

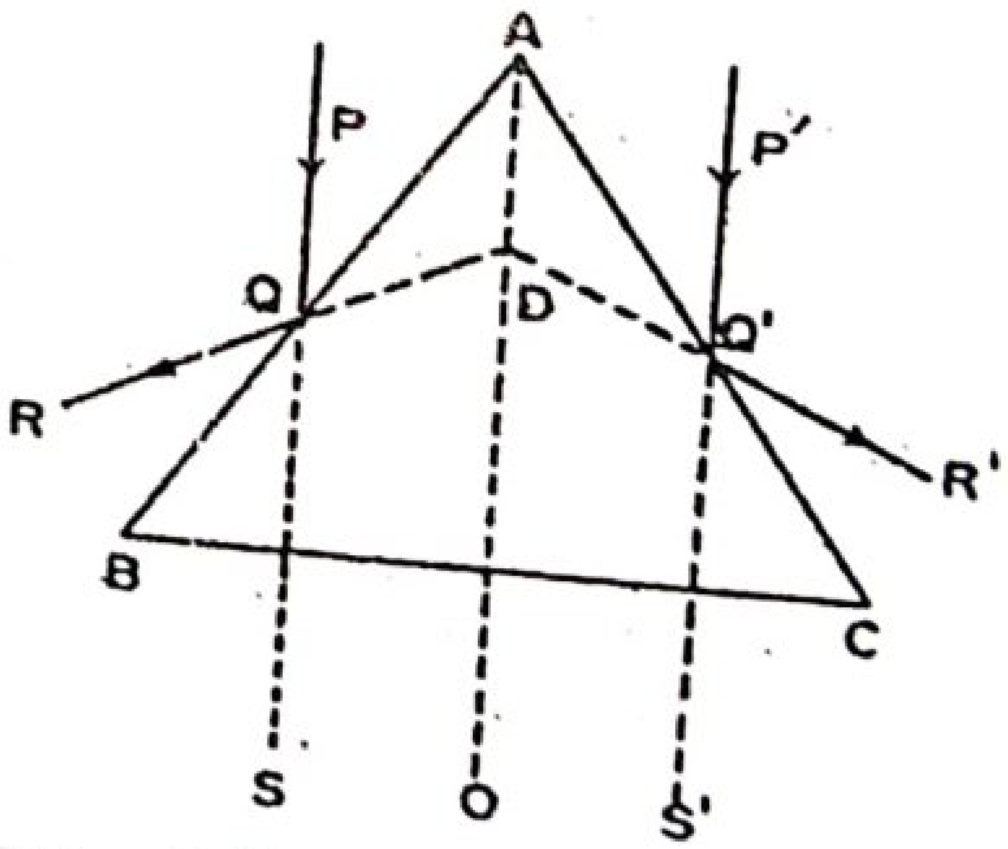


Figure 2: Determination of Prism Angle

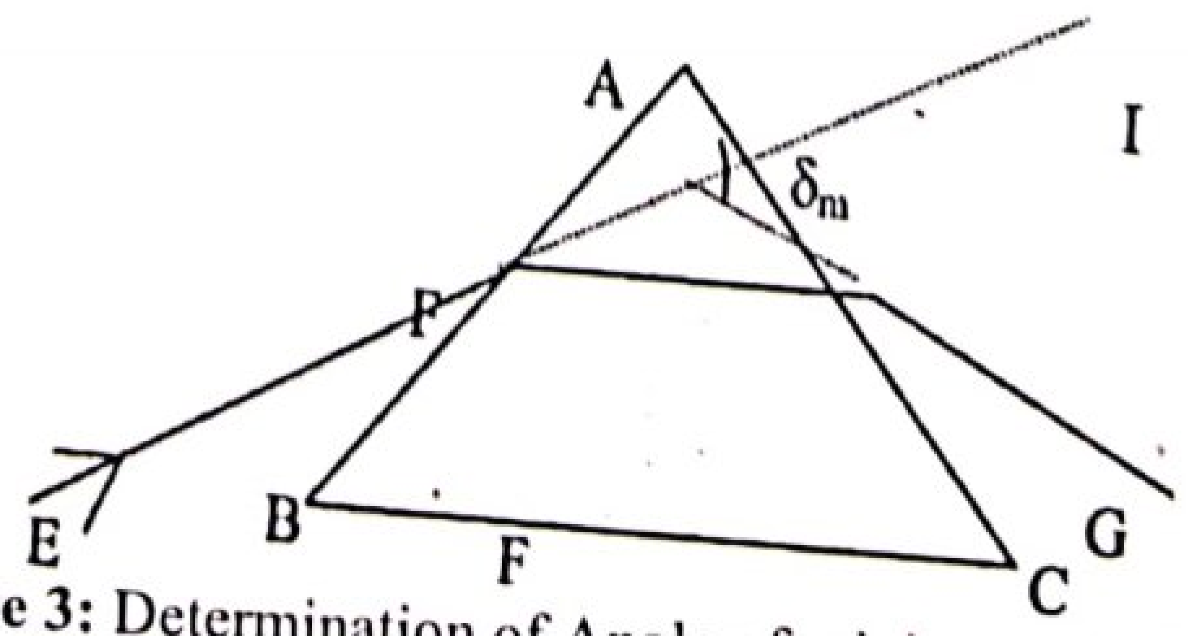


Figure 3: Determination of Angle of minimum deviation

Now when a ray of light passes through a prism it suffers refraction as shown in (Figure 3). If EF is the incident ray, FG the refracted ray and GH the emergent rays, and then the IDH is the angle of deviation. It is the angle between the direction of the incident ray and the emergent ray. The angle of deviation depends upon the angle of incidence. For a certain value of angle of incidence, the angle of deviation has minimum. If δ_m denotes the angle of minimum deviation for the given prism of refracting angle A, then the refractive index μ is given by,

$$\mu = \frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}}$$

Apparatus: Spectrometer, Sodium light, Prism, Spirit level, Magnifying glass etc.

Procedure:

1. Determine the Vernier constants of both the Vernier. Now place prism on the prism table so that its edge coincides with the center of the table. The prism is placed in such a way that the vertical plane through the axis of the collimator will cut the base BC nearly morally (Figure 2).
2. Both the Vernier should be read to avoid error due to the non-coincidence of the center of the circular scale with the axis of rotation of the telescope.
3. The axis of the telescope, the collimator and the prism table should be horizontal. The position of the eyepiece should be adjusted so that the cross wires clearly visible.
4. The telescope should be focused for infinity and the collimator should be adjusted to give a parallel beam of light. The slit should be narrow.
5. The prism should be placed with its refracting edge at the center of the prism table when finding the angle of rotating the telescope. The prism table should be leveled so that reflected image from both the reflecting faces lies symmetrically with respect to the horizontal cross-wire.
6. All preliminary adjustments of spectrometer and source are performed in the usual manner, including the focusing by Schuster's method leveling the telescope, collimator and the prism table, alignment of the source and screen, and focusing the cross-wires.
7. Parallel rays from the collimator are allowed to fall on refractive face AB and AC of the prism. After reflection form image, which can be seen by looking towards those face with the unaided eye, find the image formed by reflection from the face AB of the prism. Take the telescope to the position of the eye to receive the image.
8. Next the image formed by the reflection of rays at the other face AC is received by the unaided eye and then by the telescope.
9. Determine separately for each of the two Vernier, the difference between the two mean readings for the two positions of the telescope. Take the mean of these two differences, half of this is the angle A of the prism.
10. The operation is repeated thrice and then takes the readings for the angle of the prism.
11. Place the prism on the prism table and one of the reflecting faces say AB is perpendicular to the line joining. Rotate the table so that light from the collimator is incident on the reflecting face AB and after refraction passes out of the face AC as shown in (Figure 3).
12. Look through the face AC and locate the position of the refracted image with the naked eye. Bring the telescope in this position. Adjust its position till the image of the slit falls on the cross-wire. Now turn the prism table in such a direction that the telescope has to be towards the line of the collimator axis in order to keep image in the centre of the field of view. As the prism table is rotated in this way the angle of deviation decreases. When the position of minimum deviation is reached the stationary and further rotation of the table makes it move in the backward direction. The direction of the telescope is finally adjusted till the image is on the cross-wire in the stationary position from which it turns back in which direction the prism is rotated. The minimum deviation position is correct if the image remains stationary. Note reading on both the Vernier scales V_1 and V_2.
13. Keep the table fixed and remove the prism gently. Turn the telescope and bring it in line with the collimator and clamp it work the tangent screw of the telescope so that the image of the slit falls exactly on the vertical cross-wire. Take the reading on both the Vernier scales.

Experimental data:

A) Vernier constant of the Vernier No. I and II

Value of the smallest circular scale division= $\left(\frac{1}{2}\right)^o = 30'$

30 vernier division = 29 main scale division
1 vernier division = 29/30 main scale division
V.C.= (1-29/30) M.S.D =1/30 M.S.D

$$= = \left(\frac{1}{30}\times\frac{1}{2}\right)^o = \left(\frac{1}{60}\right)^o = 1'$$

Table 1: Determination of Angle of Prism

Vernier scale No.	No. of Obs.	Reading for left image				Reading for right image				$2\theta = M - N$ degree	Mean θ degree
		MSR degree	VD	VSR $VD \times VC$	M=S+V degree	MSR degree	VD	VSR $VD \times VC$	N=S+V degree		
V_1	1										
	2										
	3										
V_2	1										
	2										
	3										

Table 2: Determination of angle of minimum deviation δ_m

Vernier scale No	No. of Obs.	Reading for left/right image				Reading for direct image				Minimum Deviation $\delta_m = M - N$ degree
		MSR S degree	VD	VSR $V = VD \times VC$ degree	$M = S + V$ degree	MSR S degree	VD	VSR $V = VD \times VC$ degree	$N = S + V$ degree	
V_1	1									
	2									
	3									
V_2	1									
	2									
	3									

Results:

Angle of minimum deviation $\delta_m = ?$
Angle of Prism $A = ?$
Refractive index $\mu = ?$

Oral questions and their Answer:

Q1. Why the spectrometer should be leveled before its use?

Ans. Otherwise the position of the image will change with the position of the telescope i.e. it will be different for different positions of the telescope.

Q2. What is spectrometer and how are the conditions for obtaining a pure spectrum realized in it?

Ans. If the telescope of spectroscope is replaced by a photographic camera, the instrument is transformed into a spectrograph. Again for the measurement of refractive indices of a material for various spectral lines the spectroscope is provided with a circular scale and a Vernier. This arrangement is called spectrometer. It is a compact apparatus for obtaining a pure spectrum.

Q3. What are the main parts of a spectrometer?

Ans. In its simplest form it has the following main parts. i) the collimator, (ii) the telescope and (iii) the prism table.

Q4. How would you place the prism on the prism table in order to measure its angle?

Ans. The prism should be placed with its edge over the center of the prism table.

Q5. What is the function of the collimator?

Ans. Collimator produce parallel beam of light.

Q6. Why do you set the telescope for parallel rays?

Ans. If the incident rays are not parallel i.e. if they are either divergent or convergent the image focused for one position of the prism will be out of focus for other position. If the incident rays are parallel, then both the object and the image of the prism will be at infinity and the telescope once focused for the image will remain so for every position of the prism.

Q7. How do you place the prism when determining its angle by rotating the telescope?

Ans. The prism table should be placed with its refracting edge at the center of the prism table when finding the angle by rotating the telescope.

Q8. How does the deviation change with color of light?

Ans. Deviation is greater for violet then for red light. If we consider while light, then due to the difference of wave length of light, deviation will be different.

Q9. Why do you take sodium light and not white light?

Ans. Because, it gives a single image of the slit and a single value of minimum deviation, while white light gives a spectrum and the value of minimum deviation is different for different wavelength of light.

Q10. What is the condition of minimum deviation?

Ans. At the minimum deviation position the angle of incidence should be equal to the angle of emergence.

Q11. How does the deviation change with the color of light?

Ans. Deviation increases with shorter wavelengths e.g. it is greater for violet light than for red light.

Q12. How does the deviation of a ray vary with its angle of incidence?

Ans. The deviation has becomes minimum at a particular angle of incidence, but it always increases when the angle of incidence is either increasing or decreasing than that at which the deviation becomes minimum.

Q13. What do you mean by monochromatic light? Is sodium light strictly monochromatic?

Ans. Light of a particular wavelength is called monochromatic. No, sodium light is not exactly monochromatic, but we consider it as a monochromatic light. It contains light of two wavelengths of values 5890^0 A and 5896^0 A

Q14. To measure the angle of a thick prism why the edge of the prism is placed at the center of the table?

Ans. The error in the measurement of the angle of a thick prism is minimal by such placing.

Q15. Why readings of two Verniers are noted?

Ans. Both the Vernier should be read to avoid error due to the non-coincidence of the center of the circular scale with the axis of rotation of the telescope or the table.

Q16. What kind of an image does the telescope produce?

Ans. A virtual image at infinity is produced by the telescope. A real diminished image is produce by the objective of the telescope while the eyepiece produces a virtual magnified image.

Experiment 4

To Find the Wave Length of Sodium light by measuring the Diameter of Newton's Rings

Theory:

When a plano-convex lens of long focal length is placed on a plane glass plate, a thin film of air is enclosed between the lower surface of the lens and the upper surface of the plate. The thickness of the air film is very small at the point of contact and gradually increases from the center outwards. The fringes produced with monochromatic light are circular. The fringes are concentric circles, uniform in thickness and with the point of contact at the center. When viewed with white light, the fringes are colored. With monochromatic light, bright and dark circular fringes are produced in the air film.

S is a source of monochromatic light at the focus of the lens L_1 (Figure 1). A horizontal beam of light falls on the glass plate B at 45^0. The glass plate B reflects a part of the incident light towards the air film enclosed by the lens L and the plane glass plate G. The reflected beam from the air film is viewed with a microscope M. Interference takes place and dark and bright circular fringes are produced with the center dark. This is due to the interference between the light reflected from the lower surface of the lens and the upper surface of the glass plate G. Circular interference fringes produced by enclosing a very thin film of air or any other transparent medium of varying thickness between a plane glass plate and a convex lens of a large radius of curvature. Such fringes were obtained by Newton and are known as Newton's rings.

If R is the radius of curvature of the surface of the lens in contact with the glass plate G, D_n the diameter of the n^{th} dark or bright ring and λ the wavelength of the light then,

$$D_n^2 = 4nR\lambda \tag{1}$$

Now if D_{n+m} is the diameter of the $(n+m)^{th}$ dark or bright ring then we get,

$$(D_{n+m})^2 = 4(n+m)R\lambda \tag{2}$$

Subtracting (i) from (ii) we get,

$$(D_{n+m})^2 - D_n{}^2 = 4(n+m)R\lambda - 4nR\lambda$$

Or, $$\lambda = \frac{(D_{n+m})^2 - D_n{}^2}{4R(n+m-n)}$$

Or, $$\lambda = \frac{(D_{n+m})^2 - D_n{}^2}{4Rm} \tag{3}$$

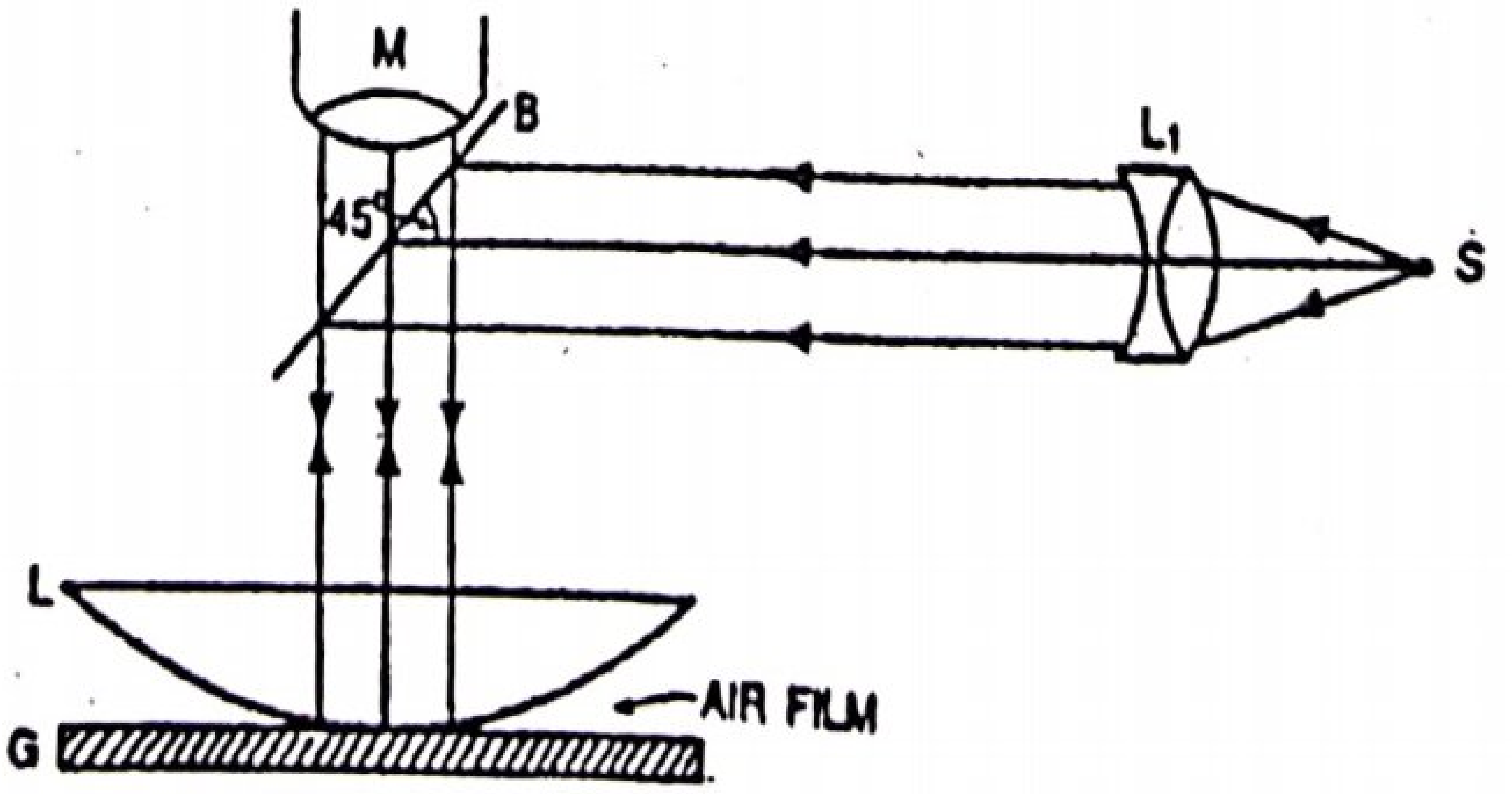


Figure 1: Formation of Newton's Ring

By measuring the diameter of the Newton's rings with the help of a travelling microscope and the radius of curvature of the surface of the lens the wavelength of a given monochromatic source of light can be determined from the above eqn. (iii).

Apparatus: A travelling microscope, sodium lamp, Newton's rings apparatus consisting of an optically plane glass plate inclined at an angle 45^0 and a convex lens.

Procedure:

1. Arrange the apparatus according to the Figure1. Level the microscope so that the scale along which it slides is horizontal and the axis of the microscope is vertical. Focus the eyepiece on the cross wires. Determine the least count of the micrometer screw of the microscope.
2. Clean the surface of the glass plate G. The lens L and the glass plate B, place the arrangement in front of a sodium lamp so that the height of the center of the glass plate B is the same as that of the center of the sodium lamp. Place a screen in between having a hole of about one-inch square in it at the same height. Place the convex lens in between and adjust its position so that a parallel beam of light is made to fall on the glass plate inclined at an angle of 45^0.
3. Adjust the position of the microscope so that it lays vertically above the center of the lens L. Focus the microscope, so that alternate dark and bright rings are clearly visible.
4. Adjust the position of the microscope till the point of intersection of the cross-wires. Coincides with the center of the ring system and one of the cross wires is perpendicular to the horizontal scale.
5. Slide the microscope to the left till the cross wire lies tangentially at the center of the 15th dark ring. Note the readings on the Vernier scale of the microscope, allied the microscope backward with the help of slow motion screw and note the reading when the cross wire lies finally at the center of the 14th, 13th …,2nd, 1st dark/bright rings respectively.
6. After reaching the 1st ring slide the microscope forwards and again notes the readings corresponding to the same in opposite direction such as 1st, 2nd, 3rd, 4th ,………, 14th, 15th on the right.

Experimental data:

Least count of the micrometer screw (L.C.):

Value of the smallest division of the liner scale = ……mm = ……cm

Pitch of the screw =…….mm = ……cm

No. of divisions in the circular scale =…………………..

Least counts of the instrument = pitch/No. of divisions of the circular scale.

L.C. =……………………..cm

The radius of curvature R of the lens L =……………………..cm

Table 1: Data for the diameter of the Newton's ring

Ring No.	Left side reading			Right side reading			Diameter of the ring D=L ~ R (cm)	D^2 cm^2
	MSR M (cm)	CSR C=CSD×LC (cm)	Total reading L=M+C (cm)	MSR M (cm)	CSR C=CSD×LC (cm)	Total reading R= M+C (cm)		
1								
2								
3								
….								
….								
14								
15								

Calculation:

If a curve is drawn with square of diameter of a ring D^2 as ordinate (y-axis) and the corresponding ring no. as abscissa (x-axis) then the graph would be straight line. Two points P_1 and P_2 are taken on this graph.

For example,

From the graph diameter square vs ring number we get,

$OR_1 = n=3$ and $OR_2 = n+m=13$

The difference of ring numbers, $OR_2 - OR_1 = (n+m) - n = (13-3) = 10$

Hence the slope of this straight line is $= \dfrac{P_2R_2 - P_1R_1}{OR_2 - OR_1} = \dfrac{D_{n+m}^2 - D_n^2}{(n+m-n)}$

The value of wavelength of Sodium light, $\lambda = \dfrac{(D_{n+m})^2 - D_n{}^2}{4R(n+m-n)}$

$$\text{Or, } \lambda = \frac{1}{4R} \times \text{Slope}$$

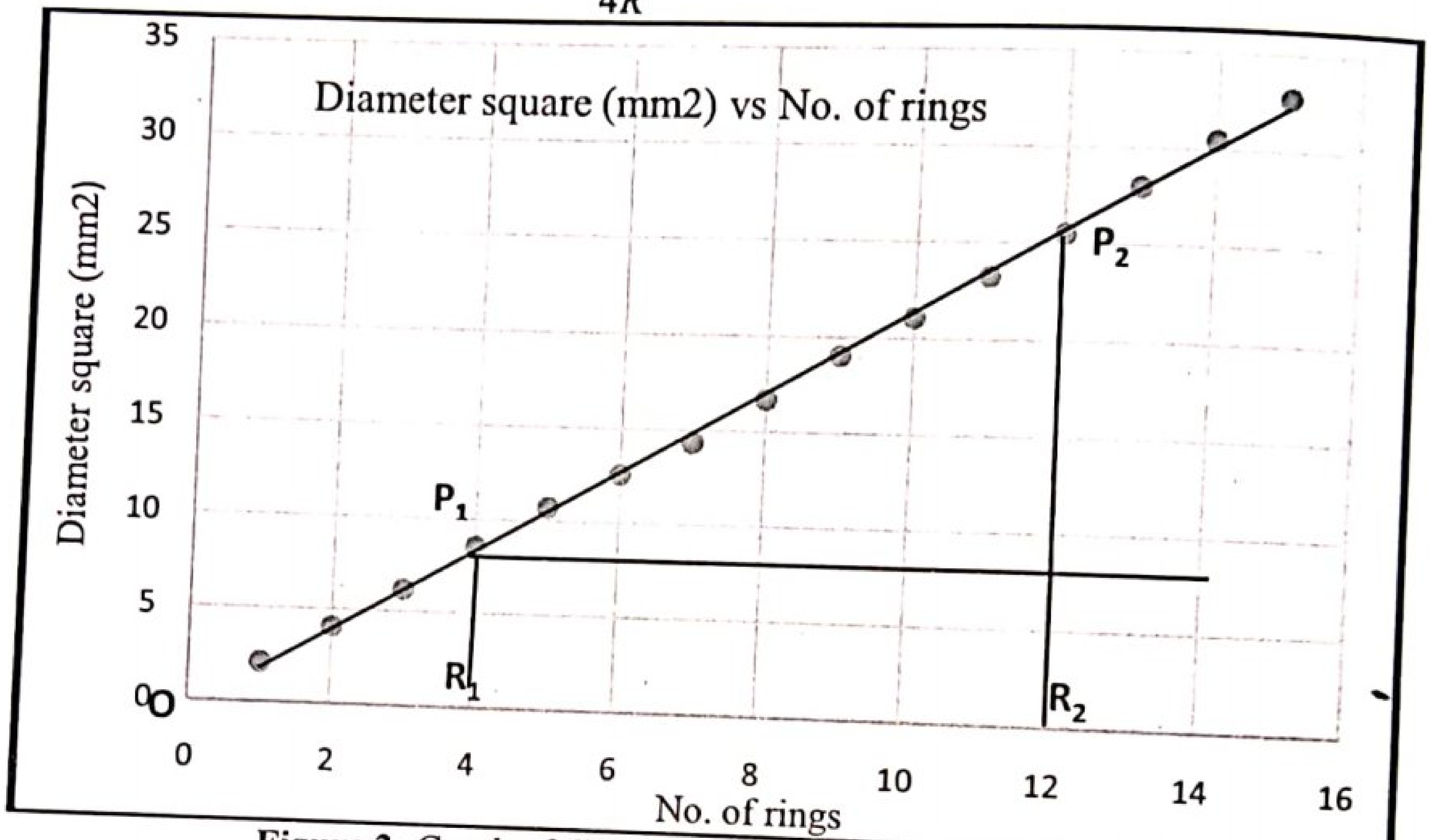


Figure 2: Graph of diameter square versus ring number.

Error calculation:

For example,

The theoretical value of the wavelength of Sodium light = λ_T

The experimental value of the wavelength of Sodium light = λ_E

So, Percentage of error, % = $\left(\dfrac{\textit{Theoretical value} - \textit{Experimental value}}{\textit{Theoretical value}}\right) \times 100$

Result:

The wavelength of Sodium light, λ = ………..A°

Precautions:

- ***i)*** The lens and the glass plate should be cleaned.
- ***ii)*** A lens of large radius of curvature should be used.
- ***iii)*** Measuring the diameter of the inner rings some error may be introduced. The cross-wire should be set mid-way between the outer and inner edges of a ring.
- ***iv)*** Sometime owing to non-uniform contact the central point may appear bright instead of dark so care should be taken to ensure a uniform contact.
- ***v)*** The micrometer screw should always be moved in the same direction to avoid the error of backlash.
- ***vi)*** Before measuring the diameters of rings, the range of the microscope should be properly adjusted.
- ***vii)*** Newton's rings can also be observed in transmitted light but in that case the rings will be less clearly defined and hence less suited for measurement.
- ***viii)*** For the purpose of the experiment, a convex lens whose radius of curvature is of the order of 100cm is suitable, otherwise the diameters of the rings will be too same and it will be difficult to measure.

Oral questions and Answers:

Q1. What is interference of light?

Ans. The distribution of light intensity due to superposition of the waves from the two coherent source of light has a constant phase relation between them and hence phenomenon in which equi-spaced bright and dark bands is produced. This phenomenon is called interference.

Q2. What are the conditions of interference?

Ans. i) Waves must come from two coherent sources, which are derived from the same source.
ii) The two sources must emit waves of same wavelength and time period.
iii) The sources should be monochromatic.
iv) The amplitudes of the interfering waves should be equal or nearly equal.
v) For brightness or darkness at a point the path difference of the point from two coherent sources must be even or odd multiples of $\lambda/2$.

Q3. Is there any loss of energy in interference phenomenon?

Ans. No, there is no loss of energy in interference phenomenon. Only redistribution of energy takes place. The energy absent at dark places is actually present in bright regions.

Q4. Is the central ring bright or dark? Explain why?

Ans. The central ring is dark. Although at center, the thickness of air film is zero but at the point of contact the two interfering rays are opposite in phase and produce zero intensity.

Q5. Is it possible to see the central ring bright?

Ans. Yes, the central ring will be bright when the rings are observed due to the transmitted light.

Q6. Where the rings are formed?

Ans. The rings are formed in the air film between the lens and the glass plate.

Q7. Are the rings equi spaced?

Ans. No, width of rings becomes smaller as the diameter of ring increases.

Q8. Why do you use monochromatic light instead of white light?

Ans. A system of clearly defined dark and bright fringes can be obtained only when monochromatic light is used otherwise the rings are colored, violet bring on the innermost side and red on the outermost edge.

Q9. Why do you use a glass plate inclined at 45^0 to the other plate?

Ans. By this arrangement the parallel beam of rays are reflected and allowed to fall normally on the lens.

Q10. Are the fringes observed in this experiment of equal thickness, or of equal inclination?

Ans. The fringes observed in this experiment are not equal thickness or have equal inclination.

Q11. Why should the diameters of the rings be accurately determined?

Ans. Otherwise we can't measure the wavelength of monochromatic light accurately.

Q12. How interference occurs in Newton's ring experiment?

Ans. When a monochromatic light is fall normally on the glass plate, a part of the incident light is reflected from the lower surface of the lens and the upper surface of the glass plate. This two reflected rays superimpose to each other and interference takes place and dark and bright circular fringes are produced.

Q13. What are Newton's rings?

Ans. Circular interference fringes produced by enclosing a very thin film of air or any other transparent medium of varying thickness between a plane glass plate and a convex lens of a large radius of curvature. Such fringes were obtained by Newton and are known as Newton's rings.

Q14. Why are the rings circular?

Ans. These rings are loci of constant thickness of the air film and these loci being concentric circle hence fringes are circular.

Experiment 5

To Determine the Wavelength of Sodium light and Resolving Power of Grating by using a Plane Diffraction Grating

Theory:

When a parallel beam of monochromatic light is incident on a grating surface, the transmitted light gives rise to primary maximum in certain directions. Now if θ be the angular deviation of light, which forms the nth order, primary maximum and (a+b) be the grating element. Then,

$$(a+b)\sin\theta = n\lambda$$

$$\therefore\ \sin\theta = nN\lambda$$

Here, $a+b = 1/N$, where N is the number of lines or ruling per cm of the grating surface.

$$\Rightarrow \lambda = \frac{\sin\theta}{nN} \qquad (1)$$

The resolving power of diffraction grating is defend as the ratio of the wavelength of any spectral line to the difference in wavelength between this line and neighboring line such that the two lines appear to be just resolved. Thus, the resolving power of a diffraction grating is,

$$\frac{\lambda}{d\lambda} = \frac{\lambda}{\lambda_2 - \lambda_1} \qquad (2)$$

Where $d\lambda$ is the smallest difference in wavelength of two lines. By measuring the angel of diffraction of the given light with the help of a spectrometer and by knowing the number of lines per cm of the grating surface, the wavelength of a given light and resolving power of grating can be determined from the above eqn. (i) and eqn. (ii) respectively.

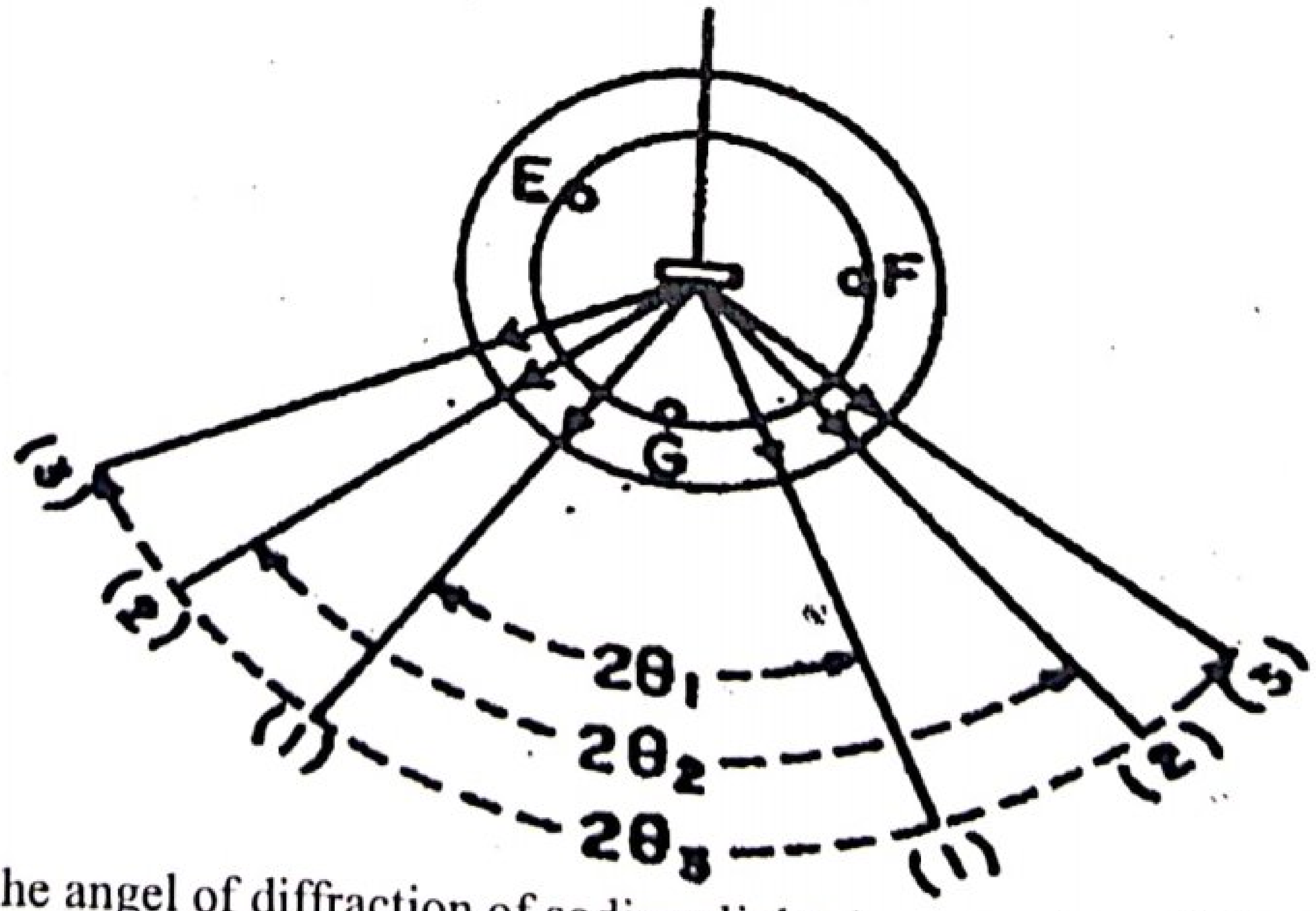


Figure 1: The angel of diffraction of sodium light due to a plane diffraction grating.

Apparatus: Spectrometer, spirit level, magnifying glass, grating with clamping arrangement etc.

Procedure:

(a) Make all the adjustments of the spectrometer including focusing for parallel rays are performed Exp. L2.

(b) Adjustment of grating:-

i) Fix the grating stand on the circular table with two screws in the holes drilled on one of the lines parallel to the line joining two of the screws. The ace of the stand to which the clamps are attached core at the center of the table. Take out the grating carefully from the box. Holding it from the edge and without touching its surface, fix it very carefully to the frame with its ruled surface towards the telescope.

ii) Optical leveling of the grating table:-
Rotate the table carrying the grating so that the plane of the grating is approximately perpendicular to the collimator. Look for the first order spectrum on one side of the direct image of the slit. Turn the telescope so that vertical cross-wire coincides with the 1storder diffracted image. If this image is not symmetrical with respect to the horizontal cross-wire, adjust it with the help of one of the screw. In this position the grating lines are parallel to the axis of the spectrometer. Now turn the Telescope to the other side that the vertical cross-wire again coincides with the 1st order diffracted image. If the adjustments are carefully done then the diffracted images of the slit will be symmetrical with respect to the horizontal cross-wire in all position.

iii) Setting the grating normal to the incident light:-
This completes the adjustments required for mounting of the grating. Set the telescope on (say) the 1st order of the diffracted image on left side of the direct image. Focus the telescope and take the reading. Then focus the telescope on the right diffracted image of the same order and take the reading. The difference between these two readings is twice the angle of diffraction for 1st order of image.

iv) Similarly measure the angle of diffraction's for the 2nd order. During these measurements the width of the slit should be as narrow as possible. In the 2nd order we will observe 2 (two) slits due to the small difference of two wavelength of sodium light. Inner image is called the D_1 and the outer image is called D_2 line. The readings for each diffracted image of sodium D_1& D_2line should be taken at least three times for three independent settings of the telescope. The cross-wires should always be focused on the same edge of the image of the slit.

v) Note the reading of the scale on both the Verniers. Note the number of lines per inch as marked on the grating and replace it carefully in the box with ruled surface upwards.

Experimental data: For example,

Vernier constant of the spectrometer (V.C.):
Value of the smallest circular scale division = $(1/2)^0 = 30'$
30 Vernier scale division = 29 main scale division

$$\therefore \quad 1\ \text{VSD} = \frac{29}{30}\,\text{MSD}$$

$$\text{V.C.} = (1\text{MSD} - 1\text{VSD}) = 1\text{MSD} - \frac{29}{30}\,\text{MSD}$$

$$= (1 - 29/30)\ \text{MSD} = (1 - 29/30) \times (1/2)^0 = (1/60)^0 = 1'$$

Number of lines per inch on the grating surface, N =....................lines/inch.
=....................lines/cm

(1 inch = 2.54 cm).

Table 1: Data for the angle of diffraction (θ).

Order of spectrum	Vernier scale No.	No. of Obs.	Reading for left image				Reading for right image				$2\theta =$ L~R degree	θ degree
			MSR M degree	VD	VSR V= VD×VC degree	Total reading L=M+V degree	MSR M degree	VD	VSR V= VD×VC degree	Total reading R=M+V degree		
1st order	V1	1										
		2										
		3										
	V2	1										
		2										
		3										
2nd order	D1 line V1											
	V2											
	D2 line V1											
	V2											

Calculation:

For 1st order image,

Here, Order, n=1

Number of lines per cm on the grating surface, N =...........lines/inch.

=...........lines/cm

Angel of diffraction, θ = ...degree

So, we know from the theory, the wavelength of sodium light is,

$$\lambda = \frac{\sin\theta}{nN} = \ldots\ldots\ldots\ldots \text{ cm} = \ldots\ldots\ldots\ldots\ldots \text{ A}^\circ$$

For 2nd order image,

Here, order, n=2

Angle of diffraction, θ_1 = ...degree

θ_2 = ... degree

So,

$$\lambda_1 = \frac{\sin\theta_1}{nN} = \ldots\ldots\ldots\ldots \text{ cm} = \ldots\ldots\ldots\ldots\ldots \text{A}^\circ$$

$$\lambda_2 = \frac{Sin\theta_2}{nN} = \ldots\ldots\ldots\ldots \text{ cm} = \ldots\ldots\ldots\ldots\ldots \text{A}^\circ$$

Thus, we know the resolving power of a diffraction grating is, $\frac{\lambda}{d\lambda} = \frac{\lambda}{\lambda_2 - \lambda_1}$

Error calculation:

Error for the wavelength of sodium light:

The theoretical value of the wavelength of Sodium light = λ_T

The experimental value of the wavelength of Sodium light = λ_E

$$\text{So, Percentage of error, } \% = \left(\frac{\textit{Theoretical value} - \textit{Experimental value}}{\textit{Theoretical value}}\right) \times 100$$

Error for the resolving power of a diffraction grating:

Similar as before

Results:

The wavelength of Sodium light, $\lambda =$ ....A°

The resolving power of a diffraction grating, $\dfrac{\lambda}{d\lambda} =$

Precautions:

The adjustment is incorrect if the angles of diffraction on the left and the right of the direct image are not equal in the 2nd order spectrum. In such a case the angle of diffraction should be found separately for the two lines and wavelengths calculated corresponding to each. The grating should be held from the edges and the ruled surface should not be touched. The telescope should be focused on the brightest image of the slit while seeing the reflected image. The ruled surface should face away from the collimator the light should fall on the whole of the surface.

Oral Questions and Answers:

Q1. What is diffraction of light?

Ans. The bending of light from edge of slit and spreading of light waves or illumination of geometrical shadow of an object is called diffraction.

Q2. What is the difference between interference and diffraction?

Ans. In interference the resultant intensity at a point is the resultant of superposition of two wave fronts coming from two coherent sources, but in diffraction phenomenon the resultant intensity at a point is due to superposition of wavelets from two parts of a single wavefront.

Q3. What is diffraction grating?

Ans. A diffraction grating is a device which consists of a very large number of closely spaced parallel slits separated by equal opaque spacing.

Q4. What is transmission and reflection grating?

Ans. Transmission grating: A plane diffraction grating consists of a very large number of narrow slits side by side. The slits are separated by opaque spaces. When a wave front is incident on a grating surface, light is transmitted through the slits and obstructed by the opaque portions. Such a grating is called the transmission grating.

Reflection grating: If the lines are drawn on a silvered surface (plane or concave), then the light is reflected from the positions of the mirror in between any two lines and such surfaces act as reflection gratings.

Q5. What is grating element, grating constant and corresponding points?

Ans. Grating element: If a be width of a slit and b be the width of an opaque space of a grating then (a+b) is called the grating element.

Grating constant: The reciprocal of the grating element (1/a+b), is known as the grating constant.

Corresponding points: When two points in the consecutive slit are separated by a distance (a+b), the grating element, and then these two points are known as corresponding points.

Q6. What happens if the number of rulings per cm. N is either increased or decreased?

Ans. If N is increased, the order number will be few but they will be separated by a large angle. If N is decreased the order number will be large, but separated by a small angle.

Q7. What is an absent spectrum?

Ans. In diffraction grating the condition for principle maximum is $(a+b)\sin\theta=\lambda$, if $(a+b)<\lambda$ then $\sin\theta>1$. This is not possible. Hence the first order spectrum is absent. Similarly the second order spectrum will be absent if $(a+b)<2\lambda$. In general if $(a+b)<n\lambda$, then the nth order spectrum will be absent.

Q8. What is the condition that the second order spectra may be absent?

Ans. In order that the 2nd order spectrum may be absent if $\frac{(a+b)\sin\theta}{a\sin\theta}=\frac{n\lambda}{\lambda}, \Rightarrow \frac{a+b}{a}=2, \Rightarrow a=b$, i.e., the width of the slit is equal to the opaque spacing between any two consecutive slits. In this case the 2nd order spectrum will be absent.

Q9. What happen if the ruled surface of the grating is directed towards the collimator?

Ans. The incident rays will be first diffracted at the ruled surface and then will be again refracted by the glass surface. Thus the angle θ is not due to diffraction alone; it will be due to diffraction and refraction.

Q10. What do you mean by ghost line?

Ans. If the rulings on a grating are not exactly equidistant or accurately parallel, then some additional lines appear near the real spectral lines. The additional lines are called ghost line.

Q11. How does a grating spectrum differ from a prismatic spectrum?

Ans. The angle of diffraction in the grating spectrum is proportional to λ when θ is not very large. But in case of the prismatic spectrum, the violet end is more drawn out than the red end. Hence the grating spectrum is a pure spectrum than prismatic spectrum.

Q12. What is replica grating?

Ans. Replica gratings are constructed from the original grating, possibly prepared by contact printing on a fine grained photo graphic plate. On the original grating surface a thin layer of collodion solution is poured and the solution is allowed to harden. Then, the film of the collodion is removed from the grating surface and then fixed between two glass plates. This serves as a plane transmission grating. This grating is called replica grating.

Q13. What do you meant by resolving power?

Ans. The ability of an optical instrument, expressed in numerical measure, to resolve the images of two nearby points is termed as its resolving power. Or, Resolving power is the ability of the instrument to show nearby spectral lines as separate ones.

Experiment 6

To determine the wavelength of various spectral lines of discharge tube by using a spectrometer and a plane diffraction grating

Theory:

When a parallel beam of light is incident on a grating surface, the transmitted light gives rise to primary maximum in certain directions. Now if θ be the angular deviation of light, which forms the nth order primary maximum and (a+b) be the grating element. Then,

$$(a+b)\sin\theta = n\lambda$$

$$\therefore \sin\theta = nN\lambda$$

Here, $a+b = 1/N$, where N is the number of lines or ruling per inch. (1 inch. = 2.54 cm) of the grating surface.

$$\Rightarrow \lambda = \frac{\sin\theta}{nN} \qquad (1)$$

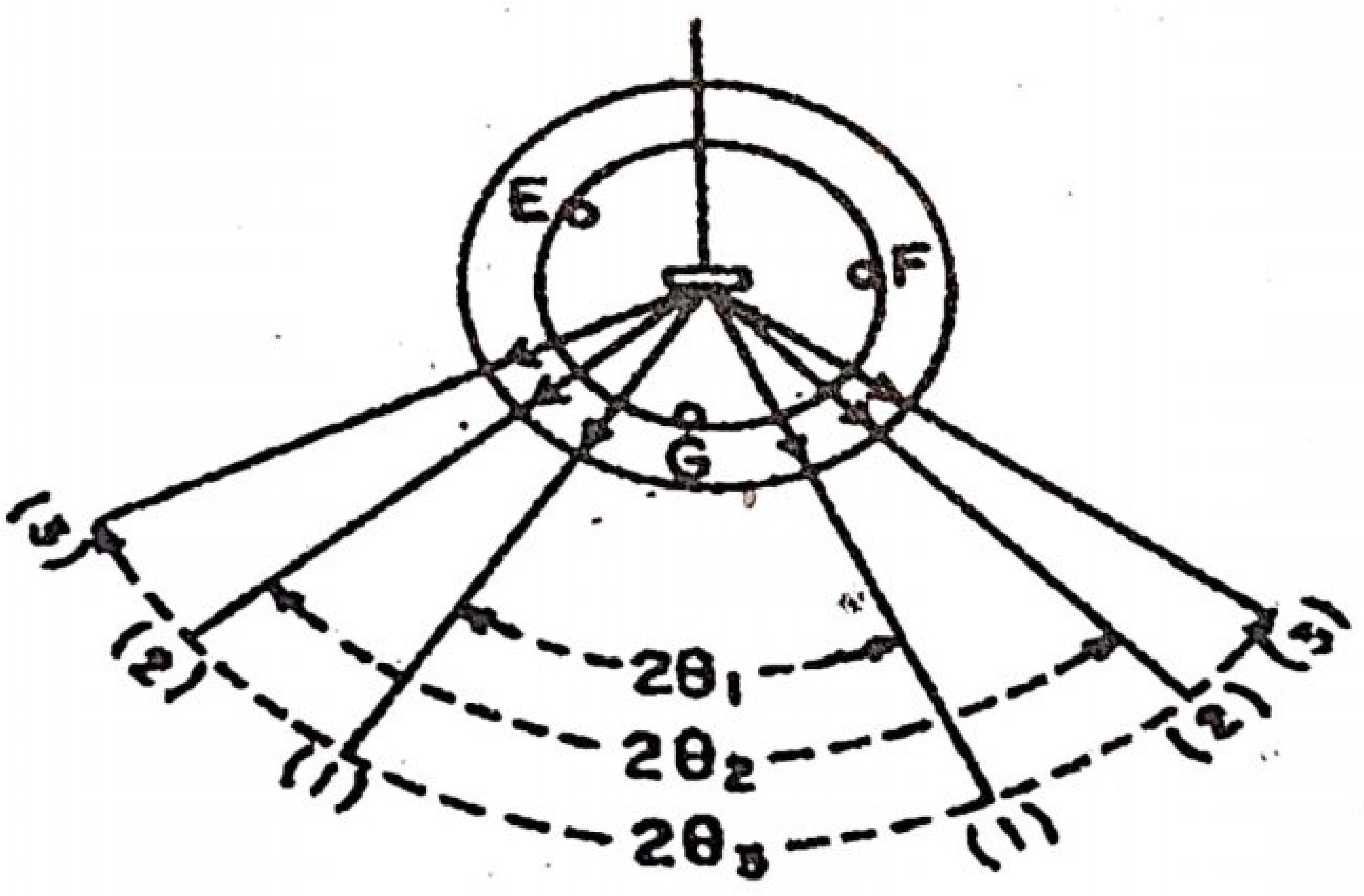


Figure 1: The angel of diffraction of various spectral lines due to a plane diffraction grating.

By measuring the angel of diffraction of the various spectral lines with the help of a spectrometer and by knowing the number of lines per cm of the grating surface, the wavelength of various spectral lines can be determined from the above eqn. (i).

***Apparatus*:** Spectrometer, spirit level, magnifying glass, plane diffraction grating, discharge tube with clamping arrangement etc.

Procedure:

A: Make all the adjustments should be made in connection with the mounting of the grating.

(i) Adjust the position of the eye-piece of the telescope so that the cross-wires are clearly visible. Focus the telescope on a distant object and set it for parallel rays. Level the spectrometer by the leveling screws and then the prism table with the help of a spirit level.

(ii) Fix the grating stand on the circular table with two screws in the holes drilled on one of the lines parallel to the line joining two of the screws meant for the purpose. The face of the stand to which the clamps are attached should be at the center of the table. Take out the grating carefully from the box. Holding it from the edge and without touching its surface, fix it very carefully to the frame with its ruled surface towards the telescope.

(iii) Rotate the prism table till you get, on the cross-wires by the telescope, and image of the slit formed by reflection at the grating surface. In this position the plane of the grating is inclined at an angle of 45° to the incident light. Read the position of the prism table, using both the verniers. Turn the table through 45° from this position so that the plane of the grating is normal to the incident light with its plane face towards the collimator. The grating is now set normal to the incident light with its ruled surface away from the collimator. Clamp the table in this position.

(iv) Now look carefully at the grating on the table and ascertain whether the surface of the grating which first receives the light is the one which also contains the lines.(Allow the light to be reflected alternately from both the surfaces of the grating and observe the image of the slit through the telescope, whose axis must be kept perpendicular to that of the collimator. It will be found that the image formed by one surface of the grating is brighter than that formed by the other surface. The surface which produces the less sharp image is the one which contains the lines). If so, turn the prism table either through 135° or 45° in the appropriate direction so that at the end of this rotation the ruled surface will face the telescope, while light from the collimator will be incident normally on the grating. If it is the unruled surface of the grating which first receives the light, then the prism table should be rotated through an angle of 45° or 135° in the proper direction to bring the grating into the position specified above. Fix the prism table in its new position.

B. To make the grating vertical: In operation above you have made the plane of the grating vertical but the lines may not be so. The grating would require a rotation in its own plane to bring this about.

(i) Rotate the telescope to receive the diffracted image on either side of the direct image. If the lines of the grating are not vertical, the diffracted image on one side of the direct image will appear displaced upwards while that on the other side will appear displaced downwards. But actually the spectra are formed in a plane perpendicular to the lines of the grating.

(ii) Now set the telescope to receive the diffracted image in the highest possible order on one side and turn the third screw of the prism table till the centre of the image is brought on the junction of the cross-wires. This screw rotates the grating in its own plane as a result of which the lines become vertical. On turning the telescope it will be observed that the centres of all the diffracted images (on both sides of the direct image) lie on the junction of the cross-wires.

C. This completes the adjustments required for mounting of the grating. Now proceed to take readings as follows:

(i) With discharge tube (say Helium) placed in front of the collimator slit, set the telescope on, say, the first order of the diffracted image on one side of the direct image. Focus the telescope and take the reading using both the verniers.

(ii) Helium discharge tube should be mounted practically in contact with the slit. Instead will now see a large number of spectral lines of different colors. Adjust the position of the discharge tube till the spectrum looks brightest. Identify the different lines of the spectrum and for each line determine the angle of diffraction. Then focus the telescope on the diffracted image of the same order on the other side of the direct image. Then we can calculate the wavelength of each of these lines. Compare them with the values obtained from the tables.

(iii) Replace the discharge tube with another say of Neon and Argon. Calculate the wavelength of the prominent lines of the spectrum in the manner described above and compare with the values given in the table.

Experimental data: For example,

Vernier constant of the spectrometer (V.C.):

Value of the smallest circular scale division = $(1/2)^0 = 30'$

30 Vernier scale division = 29 main scale division

$$\therefore \quad 1\ \text{VSD} = \frac{29}{30}\,\text{MSD}$$

$$\text{V.C.} = (1\text{MSD} - 1\text{VSD}) = 1\text{MSD} - \frac{29}{30}\,\text{MSD}$$

$$= (1 - 29/30)\ \text{MSD} = (1 - 29/30) \times (1/2)^0 = (1/60)^0 = 1'$$

Number of lines per inch on the grating surface, N =…………………lines/inch.

=…………………lines/cm

(Here, 1 inch = 2.54 cm).

Table 1: Determination of the angle of diffraction (θ) of various spectral lines by using a Helium discharge tube.

Order of spectrum	Description of the lines	Vernier No.	Reading for left image			Reading for right image			$2\theta =$ L~R degree	θ degree	θ degree
			MSR M degree	VSR V= VD×VC degree	Total reading L=M+V degree	MSR M degree	VSR V= VD×VC degree	Total reading R=M+V degree			
1st order	Violet	V_1									θ_V
		V_2									
	Bluish green	V_1									θ_{BG}
		V_2									
	Light green	V_1									θ_{LG}
		V_2									
	etc…. ..	V_1									θ_{etc}
		V_2									
2nd order	Violet	V_1									θ_V
		V_2									
	etc…. ..	V_1									θ_{etc}
		V_2									

Table 2: Determination of the angle of diffraction (θ) of various spectral lines by using a Neon discharge tube. (Same as Table 1)

Calculation:

From the theory, we know the wavelength of various spectral lines,

$$\lambda = \frac{\sin\theta}{nN}$$

Here, n= Order of the spectrum

N= Number of lines per cm on the grating surface

$\cdot\theta$=Angle of diffraction of various spectral lines

For 1st order:

For Violet light: n= 1

N =...........lines/inch. = ...lines/cm ($\because$ 1 inch = 2.54 cm)

θ_V =.............degree

So, the wavelength of Violet light is,

$$\lambda_V = \frac{\sin\theta_V}{nN} = \text{............ cm} = \text{..............} \ A^{\circ}$$

For Bluish green: n= 1

N =...........lines/cm

θ_{BG} =.............degree

So, the wavelength of Bluish green light is,

$$\lambda_{BG} = \frac{\sin\theta_{BG}}{nN} = \text{............ cm} = \text{..............} \ A^{\circ}$$

etc.......................................

For 2nd order:

Similarly........................as before

Error calculation:

For Violet light:

The theoretical value of the wavelength of Violet light =.............. A°

The experimental value of the wavelength of Violet light =.............. A°

$$\therefore \text{Percentage of error, \%} = \left(\frac{\textit{Theoretical value} - \textit{Experimental value}}{\textit{Theoretical value}}\right) \times 100 = \text{.........} \ \%$$

For Bluish green:

The theoretical value of the wavelength of Bluish green light =.............. A°

The experimental value of the wavelength of Bluish green light =.............. A°

$$\therefore \text{Percentage of error, \%} = \left(\frac{\textit{Theoretical value} - \textit{Experimental value}}{\textit{Theoretical value}}\right) \times 100 = \text{.........} \ \%$$

etc ....

Results:

The wavelength of Violet light, λ_V = ...A°

The wavelength of Bluish green light, λ_{BG} = ...A°

etc ....

Precautions:

The grating should be held from the edges and the ruled surface should not be touched. The telescope should be focused on the brightest image of the slit while seeing the reflected image. The ruled surface should face away from the collimator. The light should fall on the whole of the surface.

Oral Questions and Answers: Same as experiment number 5

Experiment 7

To Determine the Specific Rotation of Sugar solution by means of Polarimeter

Theory:

The angle of rotation of the plane of polarization produced by any substance depends upon,

i) thickness of the medium
ii) the concentration of the solution or the density of the active substance in the solvent.
iii) the nature of the substance.

Thus,

$$\theta \infty lc \text{ ; or, } \theta = slc \text{ ; or, } s = \frac{\theta}{lc}$$

Where θ the angle of rotation produced, l is the length (or thickness) of the substance in decimeters, c is the concentration in gm/cc of the solution and is a constant called specific rotation and depends upon the nature of the substance. If l=1 decimeter and c= 1 gm/cc then specific rotation may be defined as the rotation produced while traversing a path of one decimeter length in the solution containing 1 gm of the optically active substance per cc of the solution. Then,

$$Specific\ rotation = \frac{Rotation\ produced\ by\ 1\ decimeter\ length\ of\ the\ solution}{density\ of\ the\ solution\ in\ gm\ per\ cc}$$

$$= \frac{\theta}{l/10} \div c = \frac{10\theta}{lc}$$

Where the length l is expressed in cm.

The amount of rotation also depends upon the temperature and the wavelength of the light used. Then the specific rotation S at a given temperature t and corresponding to a wavelength λ is given by,

$$[S]_{\lambda}^{t} = \frac{10\theta}{lc} \qquad (1)$$

Now, by measuring the angle of rotation (θ) for different values of known concentrations (c) of a solution with the help of a polarimeter the value of the specific rotation of the solution can be determined from above eqn. (i).

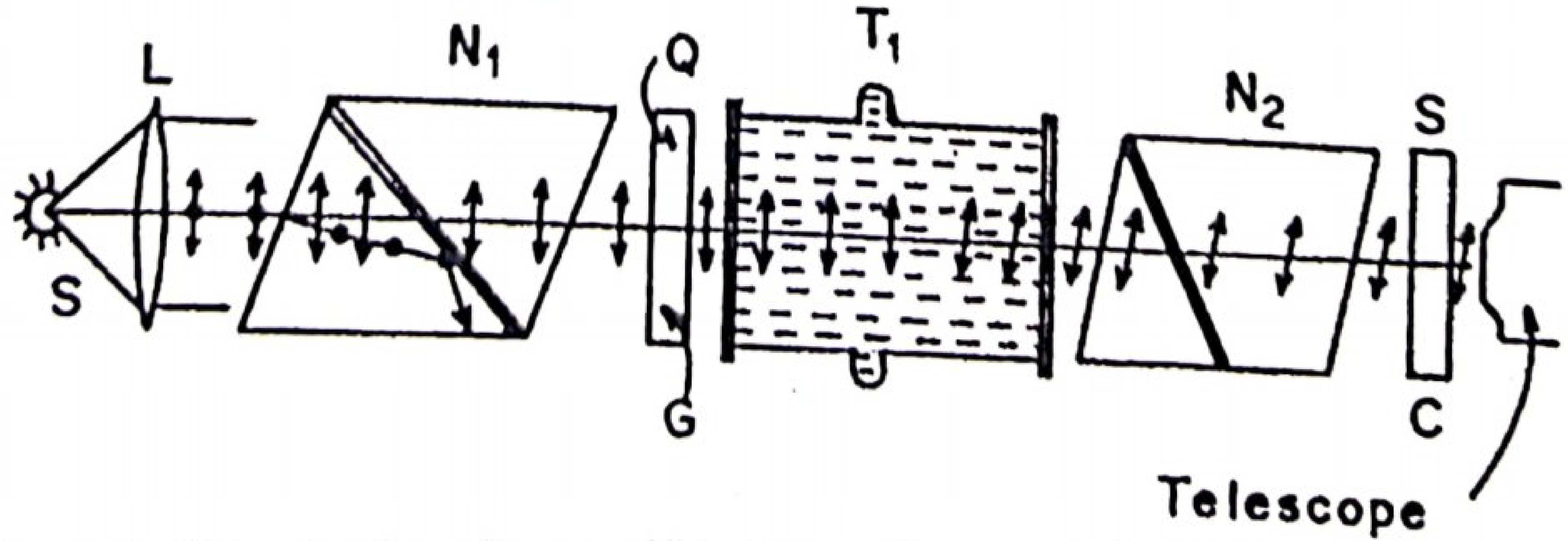


Figure 1: Determination of the specific rotation of sugar solution by means of polarimeter.

Apparatus: Polarimeter, Sodium Lamp, Sugar, weight box, graduated cylinder, two beakers, filter paper, Funnel, Eye-piece, Pipette and a glass rod.

Procedure:

i) Examine the circular scale in contact with the analyzer and find its Vernier constant.

ii) A 20% sugar solution is prepared first. This is done by dissolving 20 gms of sugar in water. After combination the mixture will be 100 cc.

iii) Remove the brass caps of the Polarimeter tube. Clean the tube as well as the glass windows. Now replace one of the caps in position taking care that no strain is exerted on the glass window. Hold the tube in a vertical position and fill it with water slip the second glass window gently on the tube taking care that no air bubbles are left underneath. It screws the cap gently taking care that no strain is exerted on the glass window.

iv) Place the tube in position in the Polarimeter and cover it. Now rotating the circular scale fill the two halves of the half shade device are in equally dark position. In this position there will be an abrupt change in the intensity of the two halves when slight rotation on either side is given. Note the reading on the scale. Turn through 180, set the analyzer again for equally dark position and note the reading on the scale.

v) Now fill the tube with 20% sugar solution prepared as explained above. Place it in position and note the scale readings when the two halves are in equally dark position.

vii) Similarly repeats the experiments as instructed by respected teachers.

vii) The operation is repeated with different concentration of sugar solutions. A curve is plotted taking concentration along x-axis and angle of rotation along y-axis. The graph will be straight line. From the graph a point it taken and for this particular point the specific rotation of the sugar solution is calculated.

Table 1: Data for the specific rotation of sugar solution

Strength of sugar solution *(Will be given by teacher)*	No. of obs.	First reading with water (P) (degree)	Second reading with solution (Q) (degree)	Angular rotation, θ= (Q-P) (degree)	Mean angular rotation, θ (degree)	Specific rotation $S = \frac{10\theta}{l\,c}$ (degree)
	1					
	2					
	3					
	1					
	2					
	3					
	1					
	2					
	3					

Experimental data:

Vernier constant (V.C.): for example,

Value of the smallest circular scale division = $(1/2)^0$

30 Vernier scale division = 29 main scale division

$$\therefore \quad 1\ \text{VSD} = \frac{29}{30}\text{MSD}$$

$$\text{V.C.} = (1\text{MSD} - 1\text{VSD}) = 1\text{MSD} - \frac{29}{30}\text{MSD}$$

$$= (1 - 29/30)\ \text{MSD} = (1 - 29/30) \times (1/2)^0 = (1/60)^0$$

Length of the tube, l=.............................cm

Calculation:

If a curve is drawn with angular rotation (θ) as ordinate (y-axis) and the concentration of sugar solution (c) as abscissa (x-axis) then the graph would be straight line through the origin.

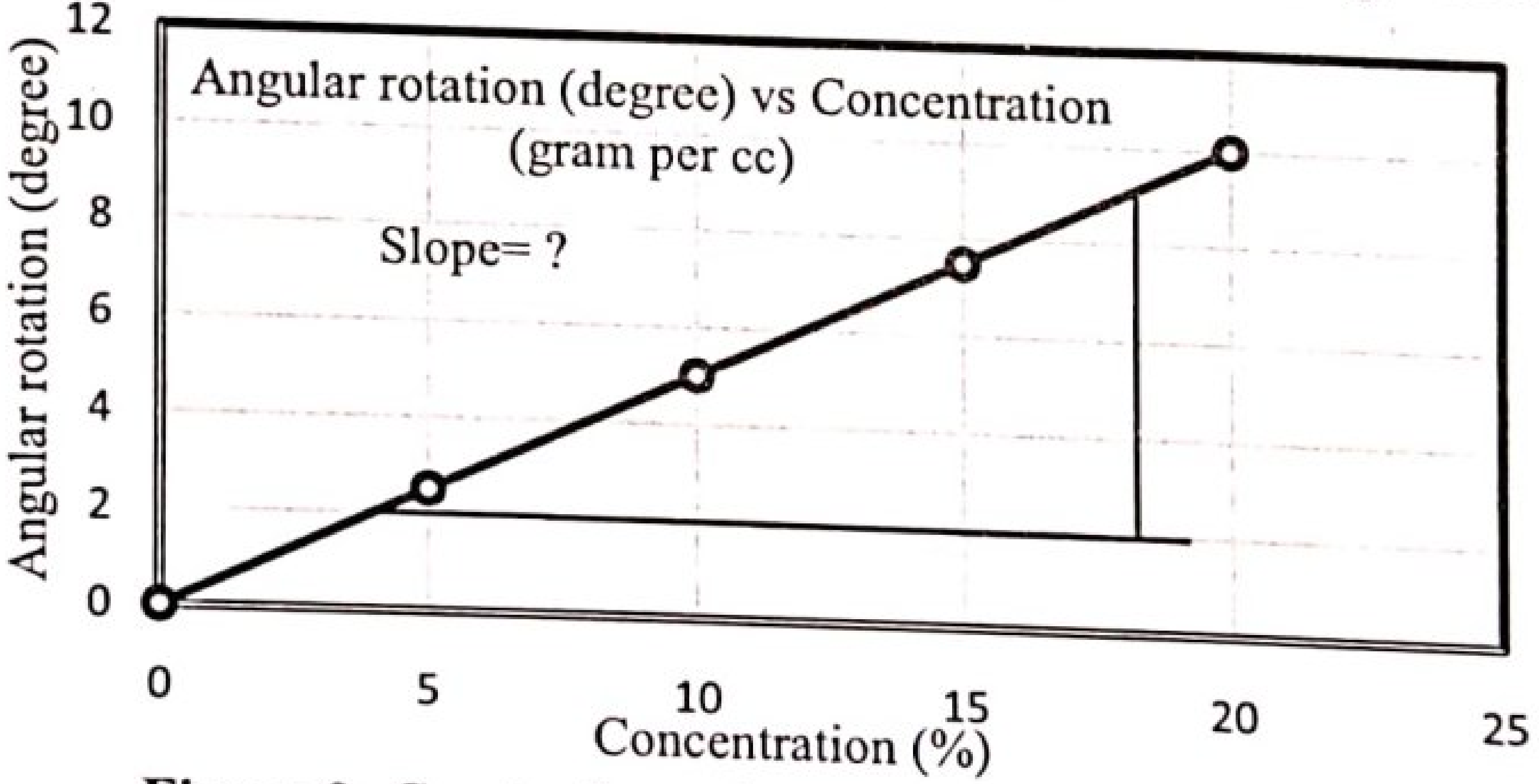


Figure 2: Graph of angular rotation vs concentration.

From the graph angular rotation (degree) vs concentration (gram per cc) we know that the slope of the straight line is,

$$\text{Slope} = \frac{d\theta}{dc} = \frac{\theta_2 - \theta_1}{c_2 - c_1} = ?$$

From theory we know that the specific rotation of sugar solution is,

$$S = \frac{10\theta}{lc} = \frac{10}{l} \times \frac{d\theta}{dc} = \frac{10}{l} \times slope = ...?$$

Where, l is the length of the tube =.........cm

Error calculation:

Percentage of error:

The theoretical value of the specific rotation of sugar solution $= S_T$

The experimental value of the specific rotation of sugar solution$= S_E$

$$\text{So, Percentage of error, \%} = \left(\frac{Theoretical\ value - Experimental\ value}{Theoretical\ value}\right) \times 100$$

Table 2: Table for standard deviation

S_i	$\bar{S}$	$(S_i - \bar{S})$	$(S_i - \bar{S})^2$	$\sum (S_i - \bar{S})^2$	n	σ
					Total number of observations	

$$\therefore \text{Standard deviation, } \sigma = \sqrt{\frac{\sum_{i=1}^{n} (S_i - \bar{S})^2}{n(n-1)}} = \ldots\ldots\ldots\ldots\ldots ?$$

Result:

The specific rotation of sugar solution, S = ………………..?

Or, the specific rotation of sugar solution, S = $\bar{S} \pm \sigma$ = ………………..?

Precautions:

The tube and the glass windows should be clean. Care should be taken so that no air bubble remains inside the tube when it is filled with the solution. The reading should be taken in the equally dark position and not in the equally bright position. The rotation depends on the temperature of the solution and temperature of both known and unknown solution should be maintained constant during the experiment. The rotation depends on wavelength. Hence Na light is to be employed to find the rotation.

Oral questions and their Answers:

Q1. What is polarization of light?

Ans. Polarization of light is the process by which light vibrations are confined to one particular direction.

Q2. What is plane polarized light?

Ans. When light is passed through crystals like tourmaline, quartz etc it acquires the property of one-sidedness, i.e. the vibration takes place only in plane in such a case the light is said to be plane polarized.

Q3. What is plane of polarization and plane of vibration?

Ans. Plane of polarization: The plane of polarization is that plane in which no vibrations occur. Plane of vibration: The vibrations occur in a plane which is at right angles to the plane of polarization is known as plane of vibration.

Q4. What is a polarimeter? What are the main parts of polarimeter?

Ans. It is an instrument used for measuring the angle of rotation of the plane of polarization by an optically active substance. The main parts of polarimeter are Two nicol prisms working as polarizer and analyzer and a glass tube between them.

Q5. What do you mean optical activity, optical rotation and angle of rotation?

Ans. Optical activity: The property of rotating the plane of vibration of plane polarized light about its direction of travel by some crystal is known as optical activity. This phenomenon is known as optical rotation.

Angle of rotation: The angle through which the plane of polarization is rotated is known as angle of rotation.

Q6. Define specific rotation.

Ans. Specific rotation for the given wavelength of light at a given temperature is defined as the rotation produced by one decimeter (10 cm) length of the solution of unit concentration.

Q7. On what factor does specific rotation depend?

Ans. Specific rotation depends upon:

i) Thickness of the medium, ii) Concentration of the solution or the density of the active substance in the solvent, iii) Wavelength of light and iv) Temperature.

Q8. Does angle of rotation and specific rotation depend on strength of sugar solution and length of the tube?

Ans. Angel of rotation is proportional to length and concentration but specific rotation is independent of these factors.

ELECTRICITY

Experiment 1

To Measure the Unknown Resistance of a Wire and to Verify the Laws of Series and Parallel Resistance by means of a Post Office box

Theory

It is one of the accurate methods for the measurements of resistance. Four resistance's P, Q, R and S are connected from quadrilateral of ACDF as given in Figure 1. A galvanometer G is connected across C and F and a cell is connected across A and D. The values of the resistances P, Q and R are so adjusted that the galvanometer shows no deflection. In such a case the points B and D are at the same potentials and it can be shown that

$$\frac{P}{Q} = \frac{R}{S} \quad or \quad S = R\left(\frac{Q}{P}\right) \tag{1}$$

Where S is the unknown resistance in the fourth arm, knowing Q, P and R, S can be calculated. When two resistances R_1 and R_2 are connected in series the equivalent resistance R_s equals the sum of the individual resistance.

$$R_S = R_1 + R_2 \tag{2}$$

Now the parallel resistance becomes

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

Therefore $$R_p = \frac{R_1 R_2}{R_1 + R_2} \tag{3}$$

Measuring R_1 and R_2 separately and the equivalent resistance R_s and R_p can be calculated. By connecting them in series and in parallel, the equations (2) & (3) may be verified.

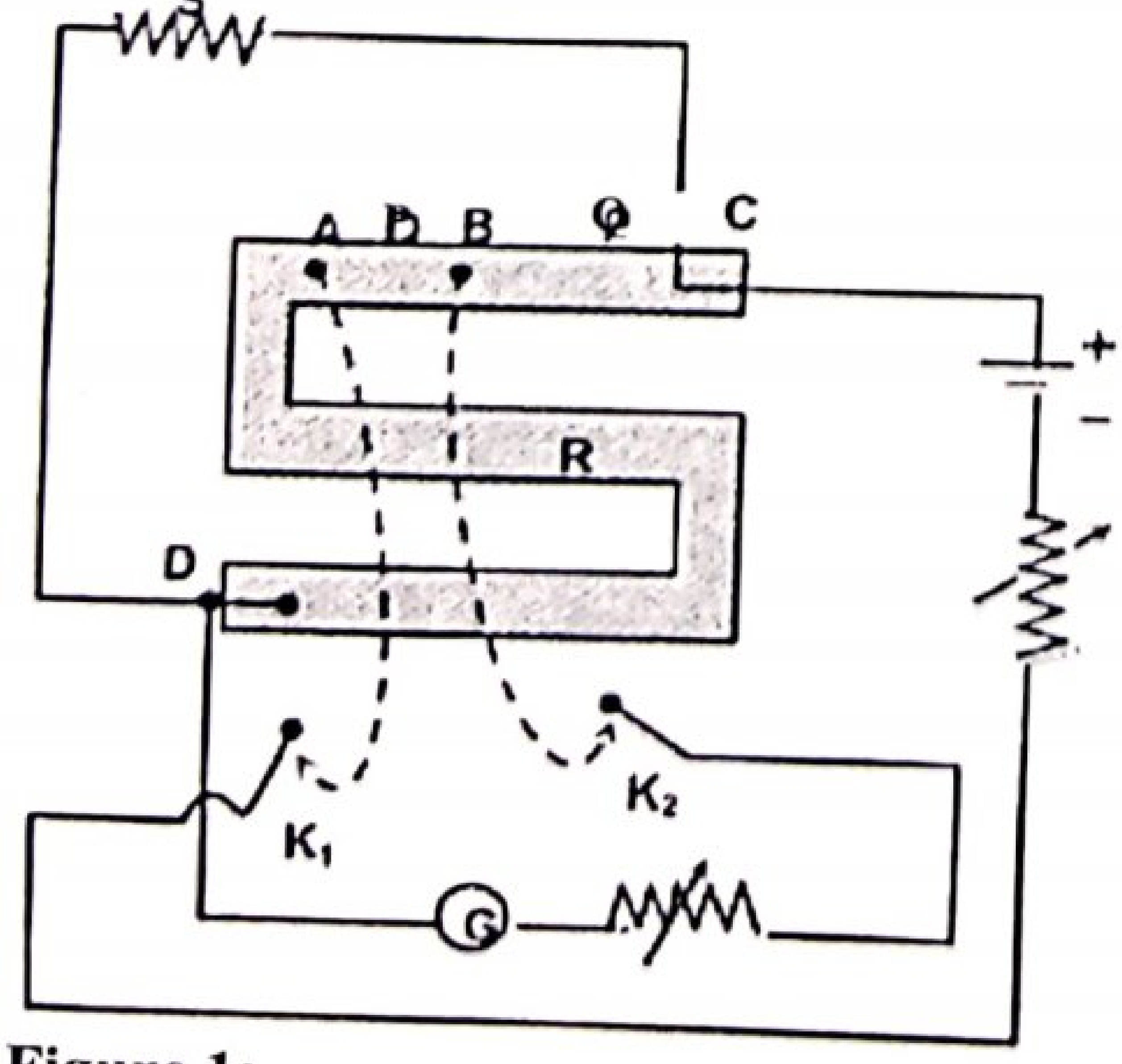


Figure 1:

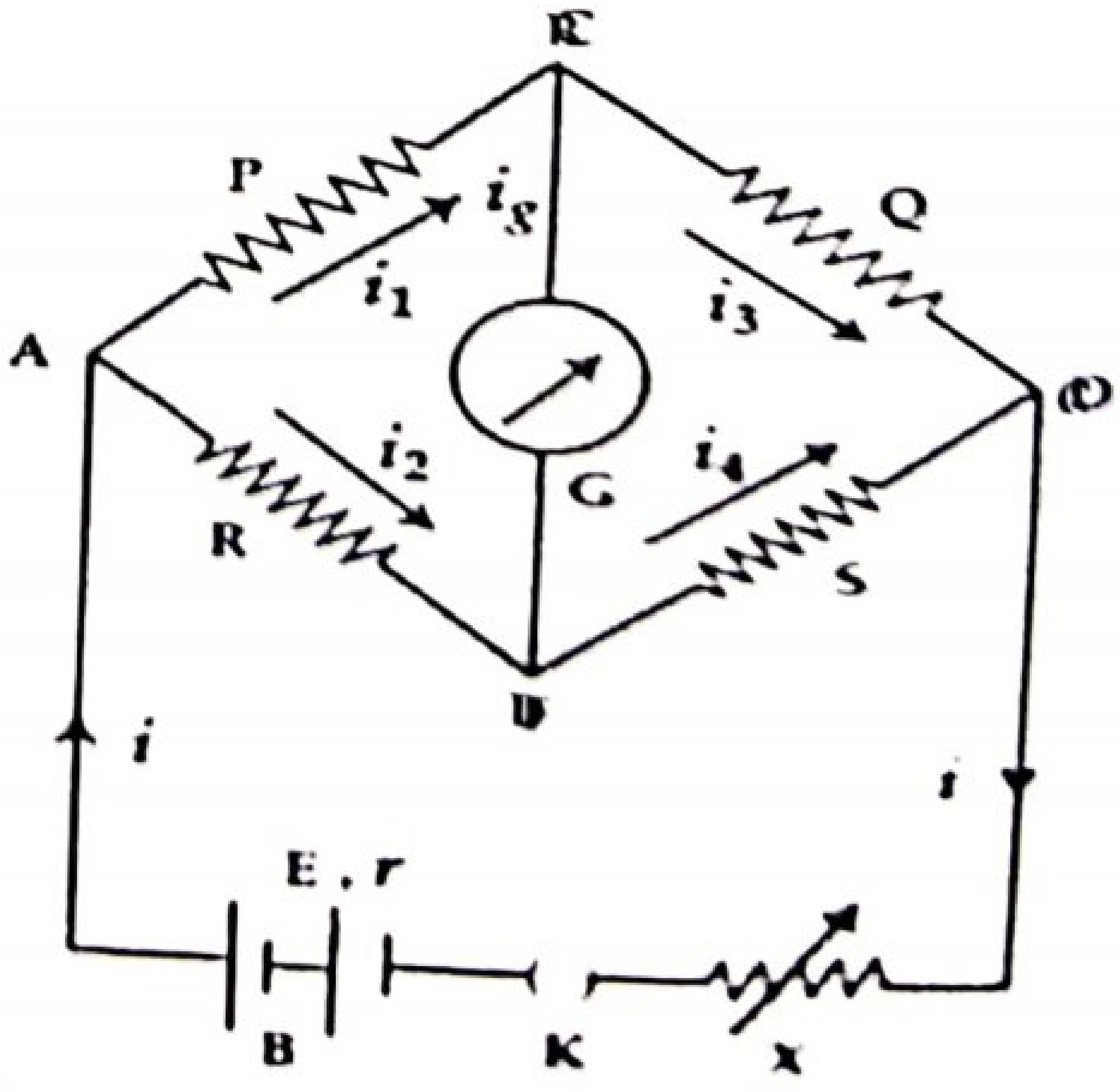


Figure 2: Wheatstone bridge Circuit

Apparatus: P.O. Box, unknown resistances, Galvanometer, Cell, Commutater, Key, Connecting wires etc.

Procedure:

i) Connections are made as in Figure1. The cell E is connected from A to C. The unknown resistance is connected through the fourth arm DF.

ii) From the ratio arms AC and CD, two resistance plug 10 ohms, 10 ohms are taken out. All other plugs are kept tight. At first the plug of the lowest resistance (viz 0) and the highest resistance (viz. infinity) are alternately inserted in the third arm AF of the box and the direction of deflection are observed by pressing the battery key K_1 first and then the galvanometer key K_2. If opposite deflections are obtained then the connection is all right, otherwise, you have to complete the connection again.

iii) The resistance in the third arm AF is gradually reduced until a resistance R_1 is obtained at which the galvanometer shows on deflection. Then the unknown resistance S is given by $S= (10/10)\ R_1= R_1$ (say 2 ohms).

iv) If instead of null point there is a deflection in one direction with R_1 and an opposite deflection with (R_1+1) in the third arm, then the unknown resistance is partly integral and partly fractional i.e. it lies between 2 and 3 ohms.

v) The experiments are repeated with 100 ohms in P and 10 ohms in Q arms so that the ratio is now Q/P=1/10. The resistance now required in the third arm to obtain the null point is 10 times of S. As the value of S lies between R_1 and (R_1+1) the resistance in the third arm now introduced is 10 times of R_1 i.e.20 and $10(R_1+1)$ i.e. 30. The opposite deflection are observed and as before the range is narrowed down to obtain two consecutive resistance R_2 and R_2+1 between which the null point lies. If $R_2 =22$ (say), $(R_2+1) =23$ the unknown resistance lies between 2.2 and 2.3.

vi) The experiments are repeated with the 1000: 10.The resistance in the third arm now required for the balance lies between 10 R_2, $(100R_1)$, i.e. 220 and $10(R_2+1)$ i.e. 230. Now a resistance R is obtained at which there may not be any deflection and the null point is obtained. Thus $S=\frac{10}{1000}\times R=\frac{R}{100}$, if R=224 then $S=\frac{1}{100}\times 224=2.24\Omega$

vii) Measure the resistance R_1 and R_2 separately by means of a P.O. Box by using procedure 1 to 6.

viii) Join the resistance R1 and R2 in series and determine the equivalent resistance of series combination by means of the P.O. Box and show that relation (2) holds good.

ix) Connected the resistance in parallel and determine the equivalent resistance of the parallel combination maintaining same procedure as described before. Show that relation (3) holds good. The average value of unknown resistance $=\frac{234+235+236}{100\times 3}=2.35$

Calculation:

From table data,

$R_1 =$ ohm
$R_2 =$ ohm

So, for the series combination, Equivalent resistance,

$$R_S = R_1 + R_2 \text{ in ohm}$$

And for Parallel Combination, Equivalent resistance,

$$R_P = \frac{R_1 R_2}{R_1 + R_2} \text{ in ohm}$$

Error Calculation: % of error for $R_1=\frac{\text{Observed } R_1 - \text{orginal value of } R_1}{\text{orginal value of } R_1}\times 100\%$

Do the same calculation for R_2, R_s and R_P.

Experimental Data:

Table 1: Data for resistance R_1 (***Given only as an example***)

Resistance in ohms			Direction of deflection	Inference for the third arm resistance is
P	Q	R		
10	10	0	Left	Too small
		∞	Right	Too large
		100	---	---
		10	---	Large
		5	---	---
		4	---	Small large
		3	---	Small
		2	Left	The unknown resistance lies between 2 and 3 ohms.
100	10	30	Right	
		20	Left	Too Small
		21	---	The unknown resistance lies between 2.3 and 2.4 ohms.
		23	---	
		24	Right	
1000	10	240	Right	Small
		230	Left	--
		234	No deflection	The unknown resistance 2.34
		235	No deflection	2.35
		236	No deflection	2.36

Table 2: Data for resistance R_2 (Table 2 is similar as Table 1)

Table 3: Data for Series resistance R_s(Table 3 is similar as Table 1, but you connect the resistances in series)

Table 4: Data for Parallel resistance R_p (Table 4 is similar as Table 1, but you connect the resistances in parallel)

Result:

The value of unknown resistances,

R_1= ohm
R_2= ohm
R_s= ohm
R_p= ohm

Discussion:

Connection should be neat and tight. The plugs of the P.O. Box should be made tight by giving them a slight twist. The battery key should be pressed first and then the galvanometer key while taking observations. A Leclanche's cell should be prepared for the purpose. Sometime it is found that limiting ranges with equal ratio do not agree with higher ratio. This may be due to (i) Looseness of plugs, which should be tight, or (ii) Resistance of some will have different values from those noted against them.

Oral question and their answer

Q1. What is a P.O. Box and why it is so called?

Ans. It is compact form of Wheatstone bridge. It was originally intended to measure the resistance of telegraphic wires in the British post office.

Q2. On what principle it works?

Ans. It works on Whetstone's bridge principle.

Q3. Why the battery key pressed first and the galvanometer key after words?

Ans. The Battery circuit should be completed before the galvanometer circuit to avoid the effect of self induction.

Q4. What condition must be satisfied to get a balance point?

Ans. The condition must be satisfied to get a balance point according to the principal of Whetstone's bridge. The unknown resistance S is given by S/R =Q/P, where Q and P are the fixed known resistance in the ratio arms and R is a variable resistance of known value.

Q5. Is it suitable for measuring high or low resistance?

Ans. Neither very high nor very low resistance can be measured, because the galvanometer will show deflection within a certain range of resistance.

Q6. Will your null point change when a cell whose e.m.f. is gradually decreasing or increasing?

Ans. No, because the distribution of potential at the two parallel branches will hang equally, maintaining the null point constant.

Q7. If the resistance of the P.O. Box were calibrated at 20°C will they givethe same value at other temperature?

Ans. No the resistance of materials increase with the increase of temperature

$$R_t = R_0\left(1 + \alpha t + \beta t^2\right)$$

where α and β are constant and it depends on the properties of the material.

Q8. On what condition Wheatstone bridge is more sensitive?

Ans. The sensitiveness of the bridge is affected by the resistance of the galvanometer and battery. The lower the resistance the greater the sensitivity of the bridge.

Q9. What are the advantages of the Wheatstone bridge method of measuring resistance over other methods?

Ans. In Wheatstone bridge method cell of any kind may be employed. The zero potential difference at the ends of the galvanometer will remain unaffected and there will be no change in the null point.

Experiment 2

To compare the E.M.F of two cells with the help of Potentiometer

Theory:

If a current I flows through the potentiometer wire of length L cm and resistance R ohms, then the potential drop per cm of the wire is IR/L volts. If the cells C_1 and C_2 require lengths I_1 and I_2 respectively of the potentiometer wire for balance then the e.m.f. E_1 and E_2 of the cells C_1 and C_2 are given by

$$E_1 = \frac{IRl_1}{L} \quad and \quad E_2 = \frac{IRl_2}{L} \qquad \therefore \frac{E_1}{E_2} = \frac{l_1}{l_2}$$

Apparatus: Potentiometer, Storage cell E, two cells C_1 and C_2, high resistance R, Rheostat R_h, Galvanometer, a three way key, connecting wires etc.

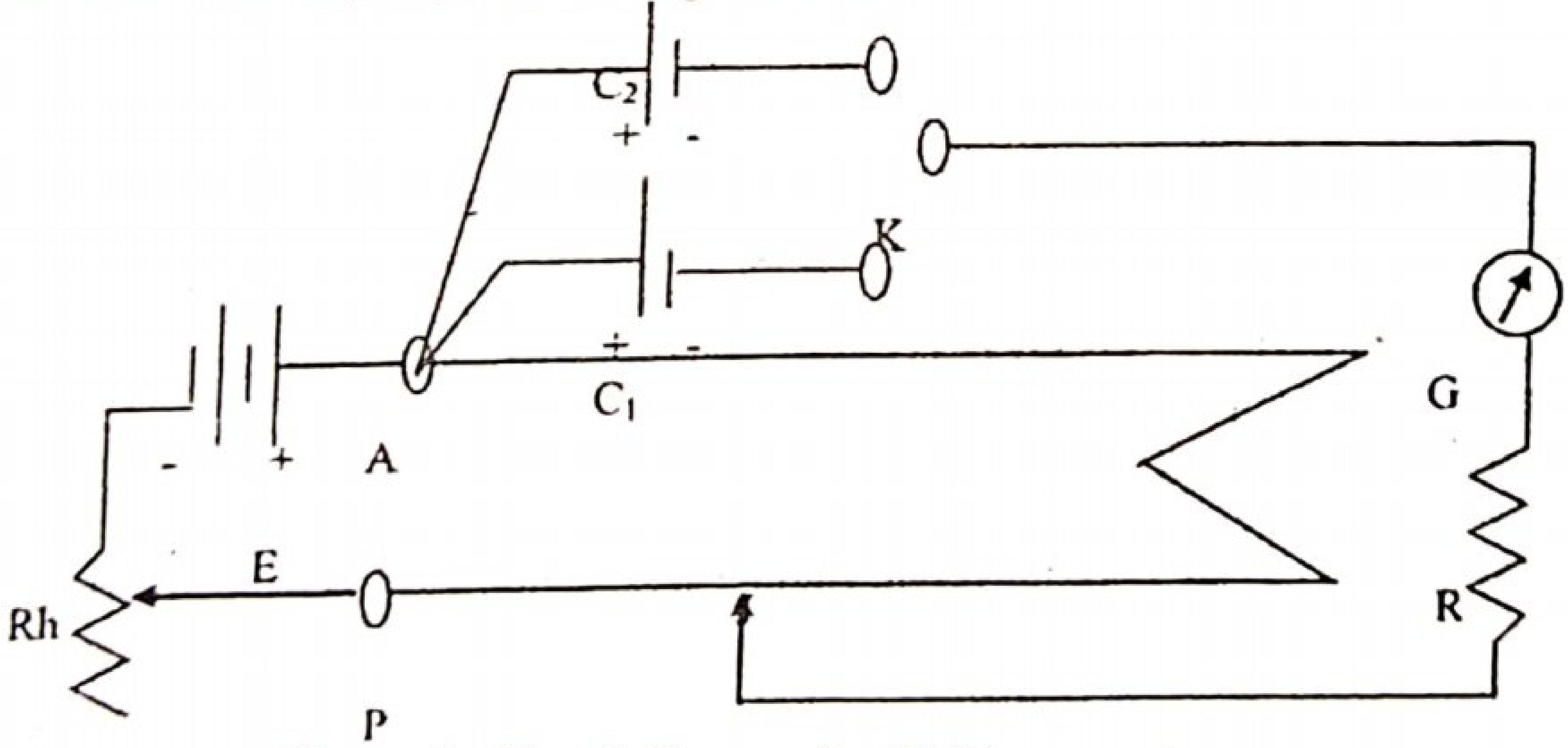


Figure 1: Circuit diagram for EMF comparison.

Procedure:

i) Connections are made as in the Figure 1. The driving battery E is connected to the end of A of the potentiometer wire and the negative terminal through the rheostat Rh and the plug key K_1 to the other end B of the potentiometer wire. Connect the positive terminals of the two cells C_1 and C_2 to A, where the positive of E is joined. The negative terminals to the binding screws S_1 and S_2 of a two-way key K_2 join the third binding screw to one terminal of the galvanometer G, and connect the other terminal of the galvanometer through the high resistance R to the jockey J.

ii) Starting with zero resistance in R_h and the maximum resistance of R_1, the two cells C_1 and C_2 are alternately connected to the galvanometer circuit. A momentary contact is established with the jockey J in the first wire and in the last wire. If the connections have been properly made and E is greater than C_1 and C_2 the deflections for both cells will be in opposite direction. In case of failing the defects must be traced and rectified.

iii) After observing the deflections in opposite directions, the approximate null points for both C_1 and C_2 obtained. With one cell (say C_1), the null point will be at a longer distance while with the other the null point will be at a distance slightly less than the former. Hence E.M.F. of C_1 is greater than C_2.

iv) Keeping the cell (say C_2) in the circuit the resistance of the rheostat is adjusted so that a null point is obtained near the middle of the last wire. After obtaining the approximate null point in this case the resistance R_1 is cut out and exact null point is secured. The null point is taken thrice and the mean values of L_1 are found out.

v) Now the other cell C_2 is joined in the galvanometer circuit (by changing the plug in the two way key) and without altering anything, the null points for this cell is also determined thrice as in (iv) above and the mean values of L_2 is found out.

vi) The value of resistance in the rheostat is then decreased (potentiometer current is increased) till this null point shifts to about the middle to the next lower wire (9th wire).The exact null point is determined for both the cells (C_1 and C_2) without any alternation of this value of R_h. Repeat the operation with lower value of R_h to get null point for C_1 and C_2 in the 8th, 7th, 6th and 5th wires and find again mean value of L_1 and L_2.

vii) The same operation is done by interchanging the cells C_1 and C_2between themselves.

Experimental Data:

Table 1: Data for comparison of EMF

No. of Obs.	Cell no.	Null Point		Total Length in cm	$E_1/E_2 = l_1/l_2$	Mean E_1/E_2
		Wire number	Scale reading in cm			
1.	First (E_1)	10th		$900+x_1$		
	Second (E_2)					
2.	First (E_1)	9th		$800+x_3$		
	Second (E_2)					
3.	First (E_1)	8th		$700+x_5$		
	Second (E_2)					
4.	First (E_1)	7th				
	Second (E_2)					
5.	First (E_1)	6th				
	Second (E_2)					
6.	First (E_1)	5th				
	Second (E_2)					

(***Prepare the same table shown in above to generate same operation by interchanging C_1 and C_2 between themselves.***)

Calculation:

For both tables, $\frac{E_1}{E_2} = \frac{l_1}{l_2}$

So, Mean $\frac{E_1}{E_2}$ =.........

Result:

From table 1, $E_1 > E_2$ (or $E_1 < E_2$)
and from table 2, $E_2 > E_1$ (or $E_2 < E_1$)

Discussions:

Null point is first determined by R_1=10,000 ohms, then with R_1 cut off. The potentiometer wire must be uniform in cross-section. The E. M. F. of the comparing cells should be less than the driver cell. It is essential that the jockey make perfect contact. When no reading is being taken the plug key K_1 should be kept open. Care should be taken that no contact between the jockey and the zero-point terminal of any wire is made. Jockey is to be pressed only to see the direction of galvanometer deflections and is then released quickly. Care should be taken at the balanced condition near zero of the scale on any wire such that the jockey does not touch any screw close to the zero point, of which a deflection may occur.

Oral questions and their Answer

Q1. What do you mean by the term E. M. F. of a cell?

Ans. E. M. F. of a cell is defined to be the potential difference in open circuit.

Q2. What is the difference between potential difference and E. M. F.?

Ans. E. M. F. is present even in the open circuit but potential difference is present only in the closed circuit. E. M. F. is the cause but potential difference is the effect.

Q3. What is the function of high resistance in series with the galvanometer? Does the null point depend on its value?

Ans. The high resistance does not in any way interfere the position of the null point. It protects the galvanometer from damage.

Q4. What is the driver cell? What is its function?

Ans. The cell E is the driver cell. Its function is to send current in the circuit so that there is a drop of potential between potentiometer terminal A and B.

Q5. Knowing the E. M. F. of one cell can you find the potential drop (ρ) per unit length of the wire?

Ans. Yes, from the relation $E_1 = \rho l_1 \; or \; \rho = E_1/l_1$. Knowing E_1 ρ can be found.

Q6. How can you increase the sensitiveness of the potentiometer?

Ans. By increasing the balancing length of the potentiometer as long as possible. The sensitiveness of the potentiometer increases.

Q7. What kind of wire should be used as the potentiometer wire and why?

Ans. Eureka, Manyanin etc. because they have high resistance, otherwise the fall of potential will not be appreciable even for the whole length of the potentiometer wire.

Experiment 3

To Determine the Resistance per unit length of Bridge Wire by Carey Foster's Bridge

Theory

The arrangement of carry-foster bridge is similar to Wheatstone bridge as shown in Figure1. P and Q are the two ratio arms, X along with resistance of wire AN and Y along with the wire resistance of the wire BN from the other two arms. It ρ is the resistance per cm of the wire AN and BN respectively and corrections at A and B are λ_1 *and* λ_2 then a balance point is obtained at N where AN=l_1 then

$$\frac{P}{Q}=\frac{X+(l_1+\lambda_1)\rho}{Y+[(100-l_1)+\lambda_2]\rho} \qquad (1)$$

If now, X and Y are interchanged and the balance point is obtained at N' such that AN'=l_2 then

$$\frac{P}{Q}=\frac{Y+(l_2+\lambda_1)\rho}{X+[(100-l_2)+\lambda_2]\rho} \qquad (2)$$

From equation (1)

$$\frac{P}{Q+P}=\frac{X+(l_1+\lambda_1)\rho}{Y+[(100-l_1)+\lambda_2]\rho+X+(l_1+\lambda_1)\rho}$$

$$\frac{P}{Q+P}=\frac{X+(l_1+\lambda_1)\rho}{Y+X+[100+\lambda_1+\lambda_2]\rho} \qquad (3)$$

Similarly from equation (2)

$$\frac{P}{Q+P}=\frac{Y+(l_2+\lambda_1)\rho}{X+[(100-l_2)+\lambda_2]\rho+Y+(l_2+\lambda_1)\rho}$$

$$\frac{P}{Q+P}=\frac{Y+(l_2+\lambda_1)\rho}{Y+X+[100+\lambda_1+\lambda_2]\rho} \qquad (4)$$

Now from equation (3) and (4) we get

$$\frac{X+(l_1+\lambda_1)\rho}{Y+X+[100+\lambda_1+\lambda_2]\rho}=\frac{Y+(l_2+\lambda_1)\rho}{Y+X+[100+\lambda_1+\lambda_2]\rho}$$

$$X+(l_1+\lambda_1)\rho=Y+(l_2+\lambda_1)\rho$$

$$X+l_1\rho=Y+l_2\rho$$

$$X=Y+(l_2-l_1)\rho \qquad (5)$$

Now if the extreme left gap is connected by a thick copper strip, then x=0 and the equation (5) becomes

$$\rho=\frac{Y}{l_1-l_2} \qquad (6)$$

Hence knowing Y, ρ can be calculated.

Apparatus

Carry-Foster Bridge, Two equal resistances, thick copper strip, a fractional resistance box and a cell, Galvanometer, Rheostat, connecting wire

Procedure:

i) Draw a diagram showing the scheme of connections as in Figure 1. Mark the gaps 1, 2, 3 and 4.

ii) Clean the Ends of the connecting wires and the thick copper strip with sandpaper.

iii) Connect the two equal resistances P and Q in the inner gaps 2 and 3. If P and Q are two resistance boxes, take out 5 ohms plug from either and make all other plug tight. Connect the thick copper strip X in the gape 4 connect one terminal of the galvanometer to the control terminal C and the other to a Jockey J. Connect the cell E between A and C.

iv) Make the plugs of the fractional resistance box tight by giving to each plug a slight twist and touch the jockey on the wire at the end F. Note the direction of deflection. Now touch it at the other end, if the direction of deflection is reversed the connections are correct.

v) Without taking any plug from the Fractional resistance box, adjust the position of the jockey to obtain a balance point and note the reading. Now inter change X and Y. Do same operations and obtain the balance point again. Note the reading.

vi) Take out 0.1ohm plug from the fractional resistance box Y and X and obtain the balance point. Note the reading and inter change X and Y. Again obtain the balance point and note it.

vii Repeat the observation with the values of Y equals to 0.2, 0.3. 0.4 and 0.5 etc.

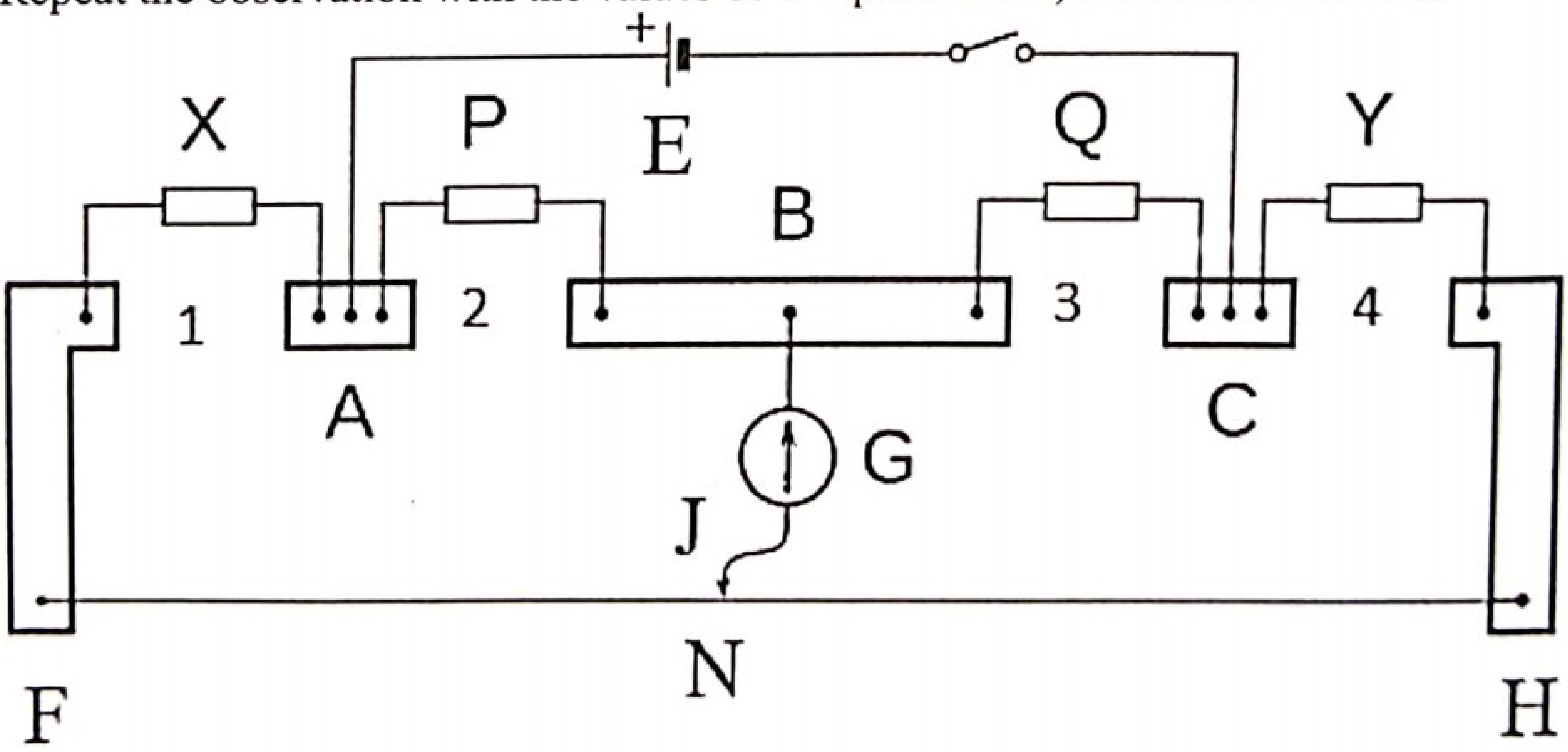


Figure 1: Carey Foster's Bridge

Table 1: Measuring the resistance per unit length.

Sl. No.	Applied resistance in ohm		Null point (l_1 and l_2) cm	(l_1-l_2) cm	$\rho = \frac{Y}{l_1 - l_2}$ ohms/cm	Mean ρ ($\overline{\rho}$) ohms/cm
	Left gap	Right gap				
1	X=0	Y=0.1	l_1=			
	Y=0.1	X=0	l_2=			
2	X=0	Y=0.2	l_1=			
	Y=0.2	X=0	l_2=			
3	X=0	Y=0.3	l_1=			
	Y=0.3	X=0	l_2=			
4	X=0	Y=0.4	l_1=			
	Y=0.4	X=0	l_2=			
5	X=0	Y=0.5	l_1=			
	Y=0.5	X=0	l_2=			

Calculation:

From table, Resistance per unit length,

For Y= 0.1 ohm, $\rho = \frac{Y}{l_1 - l_2} =$ ohms/cm

....

....

Mean Resistance per unit length, $\bar{\rho} =$ ohms/cm

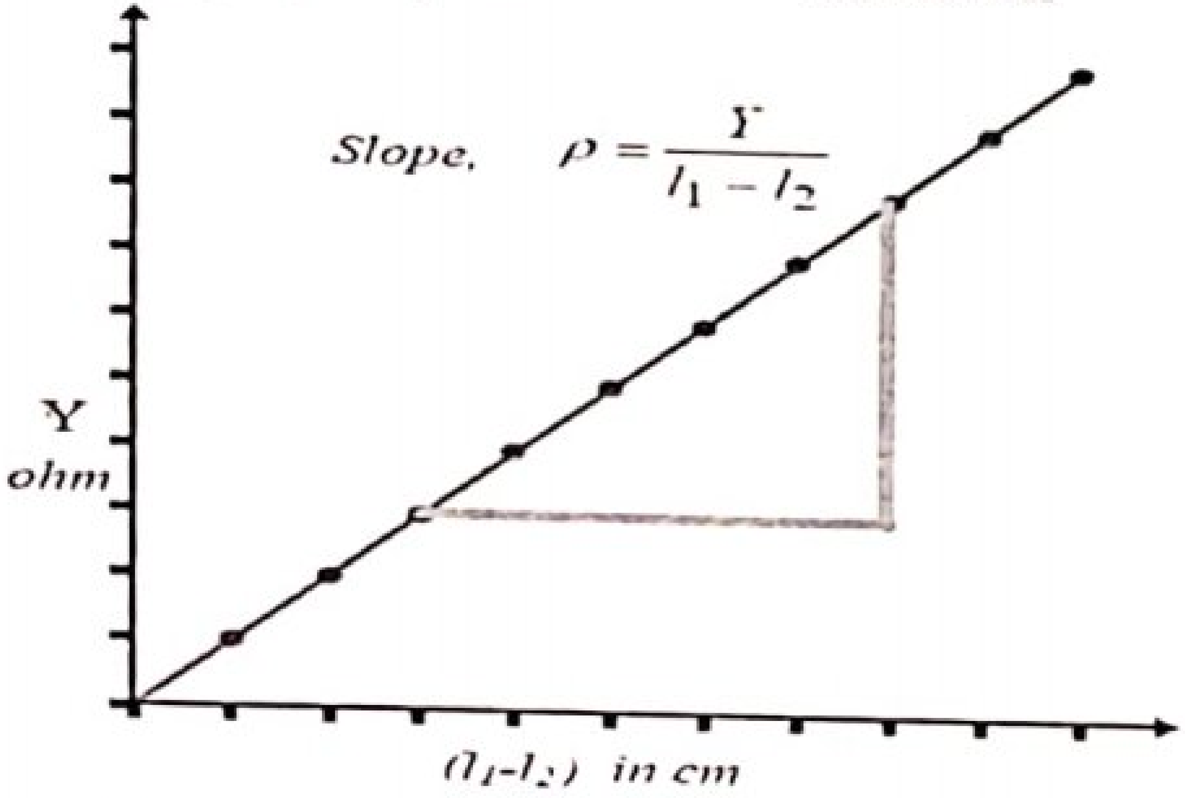


Figure 2: Y vs $(l_1 - l_2)$ graph

Graph:

Draw a graph between Y vs $(l_1$-$l_2)$ the graph must be like a straight line with positive slope. Then determine the slope of the line. This value of the slope will be the value of the resistance per unit length.

Error Calculation:

1) **Standard Deviation:**

From table 1, using the value of ρ, the standard deviation can be calculated using the following table,

Table 2: Table for standard deviation

ρ_i	$\bar{\rho}$	$(\rho_i - \bar{\rho})$	$(\rho_i - \bar{\rho})^2$	$\Sigma(\rho_i - \bar{\rho})^2$	n	ρ_s
					Total number of observations	

$\therefore$ Standard deviation, $\rho_s = \sqrt{\frac{\Sigma\,(\rho_i - \bar{\rho})2}{n(n-1)}} =$ ....?

2) Percentage of error:

$$\% \text{ of error for } \rho = \frac{\text{Observed value of } \rho - \text{ orginal value of } \rho}{\text{orginal value of } \rho} \times 100\%$$

Results:

From table 1, Resistance per unit length, $\rho = \bar{\rho} \pm \rho_s$.

From graph, Resistance per unit length, $\rho = \dfrac{Y}{l_1 - l_2}$ = Slope.

Discussions:

The end of connecting wires thick copper strip and the leads for the resistance box should be properly cleaned. The unknown low resistance should be connected to the bridge by thick copper leads. The plugs of the fractional resistance box should be tight. The battery key should be taken out while interchanging X and Y to avoid heating of the bridge wire. The jockey should be touched gently and should not be kept pressed on to the wire while shifting it from one point to other. The difference between X and Y should not be more than the resistance of the bridge wire.

Oral questions and their Answers:

Q1. What is Carey-Foster's bridge?

Ans. It is a modification of the meter bridge designed to measure the difference between two resistances of nearly equal values.

Q2. What should be the order of the resistance P and Q?

Ans. Two resistance boxes P and Q nearly equal resistance of 5 or 10 ohms are connected in the inner gaps.

Q3. What is ρ?

Ans. ρ is the resistance per unit length of the wire.

Q4. Will the presence of the end error in the bridge influence your result in any way?

Ans. No it is evident from the theory that is independent of end error.

Q5. Why is it not desirable to measure ρ with P.O. Box?

Ans. P.O. Box method is only a rough method and not accurate.

Q6. At what temperature you have done your experiment?

Ans. At room temperature.

Q7. Can you compare two nearly equal resistances by this method? If so what is the limitation?

Ans. Yes, but their values should not differ by more than the total resistance of the bridge wire.

Q8. When the bridge is most sensitive?

Ans. The bridge is most sensitive when the four arms are of equal resistance, the battery and the galvanometer resistance each equal to that of one of the arms.

Modern Physics

Experiments - 1

To investigate the photoelectric effect hence calculates the value of Planck's constant and photoelectric work function using a photo-electric cell and draw the characteristic curve of the phototube (current vs forward voltage curve)

Theory:

When light from the light source is passed through a color filter, it is possible to determine the energy of the electrons by applying a small voltage to the tube in the reverse direction to determine the voltage that stops all the electrons travelling from cathode to the anode. When the current is no longer flowing, the value of this voltage is a measurement of the level of energy of the most energetic electrons. This means that the electrons were excited by the photons of the highest frequency (Shortest wavelength) component of the light beam entering the phototube. Each colored filter has a different wavelength associated with it. It takes a different backing voltage to stop the current created by different wavelengths. Therefore, the energy of the photon that was transferred to the electron depends on the wavelength of the light. By using the different filters and recording the backing voltage values for each color, it is possible to make a plot of backing voltage versus frequency. The plot will be a straight line. The energy of a photon is proportional to the light, and the energy is higher from higher frequencies. A photon behaves like a particle when it transfers energy to an electron. A photon behaves like a wave when if reflects or diffracts to create interference patterns through slits or gratings.

The photoelectric effect occurs when light greater than certain threshold frequencies impinges on the surface of, metal and causes electrons to be ejected from the surface of the metal. Assuming that light interacts with the surface of the metal as photons of wavelength, λ, the energy carried by the incoming radiation can be expressed by the following relationship:

$$E_p = h\nu$$

Where,

E_p= quantum of energy of the photon

h= Planck's Constant (6.626×10^{-34}Js)

ν= frequency of light (Hz or s^{-1})

When the photon impinges on a solid, this energy is transferred. If the energy (E) exceeds the characteristics energy that is required to remove an electron from the surface of the solid (solids work function, ϕ), the resulting Kinetic energy of the electron, E_k, can be seen to be the balance of the transferred energy:

$$E_k = E_p - \phi$$

The experiment measures the point where the stopping potential acting on the electron just equals the K.E.:

$$E_k = Ve$$

Where, e = charge of an electron (1.609×10^{-19}C), V= Stopping potential

Using the relationship between frequency and wavelength of the photon,

$$c = \nu\lambda$$

Where c = speed of light (2.998×10^{8}m/s), λ= wavelength (nm)

we can substitute and making the following rearrangements

$$E_p = h\nu$$

Or $$E_k = h\nu - \phi$$

Or $$E_p = hc/\lambda - \phi$$

Or $$Ve = hc/\lambda - \phi$$

So $V = hc/(\lambda e) - \phi$

Therefore, a plot of V vs $1/\lambda$ will have a slope of hc/e and y intercept ϕ. Plank's constant can be estimated as h= (slope×e)/c.

The Purpose of the Photon Energy experiment:

To measure the energy of photons, we need to detect but not measure the current through the photo tube. Photons of different energies excite electrons to different energies. The experiment is to determine the highest energy level to which the electrons have been excited by the photons. There will be only a small percentage of electrons from the cathode to the anode with these highest energies. A small reverse voltage (anode negative, cathode positive) is applied just high enough to completely stop the flow of electrons. This reverse voltage is called the backing voltage. When all the electrons stop flowing (zero current), the voltage has repelled the electrons, including the ones with the highest energy acquired from the photons.

Filters placed in the path of light will pass frequencies below their cut off frequency. Most wavelengths of light will drive electrons from the cathode, but the wavelength of the particular filter is the shortest wavelength (highest frequency) of light that can pass through the photo tube.

Apparatus: Photoelectric cell; color filters; high power tungsten lamp; digital voltmeters.

Procedure:

A. For investigating the Photoelectric effect:

1. Select experiment 1 and power up the instrument.
2. Turn the ADJUST knob counterclockwise to set backing volts the zero.
3. Set the meter switch to read tube current high (0-20 μA).
4. Set up a light source (e.g., incandescent light or mercury arc lamp) so that it faces the aperture at the back of the unit. The meter will show current flowing through the tube, which is caused by photons from the light source striking the cathode and driving off electrons.

B. For investigating the dependency of Energy in a photon on the frequency of the light:

With the light source illuminating the phototube on the back of the unit and a colored filter in place, observe the current flowing and find the backing volts that just stop the current. Plot backing volts versus frequency for each light source/ filter combination.

Steps:

1. Select experiment 1 and power up the instrument.
2. Set up a light source so that it faces the aperture at the back of the unit. Add the filter and secure with tabs on the back of the unit.
3. Select tube current low (0-200nA) to see current flow.
4. Increase the backing voltage to get exactly zero current flow at the low amps setting (0-200nA).
5. When current is at exactly zero, select backing volts by turning the back knob to the appropriate position.
6. Read the backing voltage of the LCD display and record the value.
7. Note the wavelength of the filter used and the backing voltage required for the particular wavelength. Repeat steps 3-6 three times in order to obtain an average reading of the backing volts for the particular wavelength.

8. Change out the filter (new color/ wavelength) and repeat the experiment until all the colored filters available have been utilized with the light source chosen (e.g., incandescent bulb or mercury arc).
9. Convert each wavelength to frequency (Hz or s^{-1}). Sample calculations show below. Make a plot of volts versus frequency. The graph should be a straight line.

Quick Overview

1. We set current at nA and set a specific filter back of the instrument.
2. Adjust the backing voltage until the current shows zero. (Meter reading will be on tube current (0-200 nA)).
3. When the screen shows zero current we set (meter reading) nob at backing voltage and take reading, this voltage will be the required reverse voltage.
4. Repeat this experiment for other two filters and finally sketch a graph voltage (backing) vs frequency (incense of wavelength).

C. Characteristics curve of the Phototube:

1. Select experiment 2
2. Connect an adjustable power supply to the red and black sockets on the front of the unit. The power supply must be in the range of 0-20V DC. Voltage is not a backing voltage in this experiment because voltage applied to the tube is in a forward direction to encourage electron flow from the cathode to the anode.
3. Shine an incandescent light source on the aperture at the back of the unit. Do not use filters.
4. Select tube current high (0-20μA).
5. Gradually increase the applied voltage from 0 to about 20V DC.
6. Plot the relative phototube current in micro amps against the applied forward voltage to obtain the characteristics curve of the phototube.

Investigations:

Table 1: Data for frequency vs backing voltage curve

No. of Obs.	Applied wavelength, λ (nm)	Frequency, ν (Hz)	Backing Voltage (V)	Average Backing Voltage (V)	Kinetic Energy (eV)

Table 2: Data for the characteristic curve of the phototube

No. of Obs.	Applied forward Voltage (0-20 V)	Photo-current (μA)
1.		
2.		
3.		
4.		
5.		
…		
15.		

Calculation:

Sample calculation for 670nm:

$c = \lambda \nu$

c = speed of light (3×10^8m/s)

λ= wavelength (m)

ν= frequency (s^{-1})

$\nu = c/\lambda$

$$\nu = \frac{3.00 \times 10^8}{6.70 \times 10^{-7}} \ s^{-1}$$

$\nu = 4.48 \times 10^{14} \ s^{-1}$

Example for calculating Planks Constant:

Using the data collected for the various light source / filter combinations, make a plot of stopping voltage (V) vs $1/\lambda$ (nm^{-1}). Sample calculations are showing below for a plot with a line regression of $y = 1183.4x - 1.1418$.

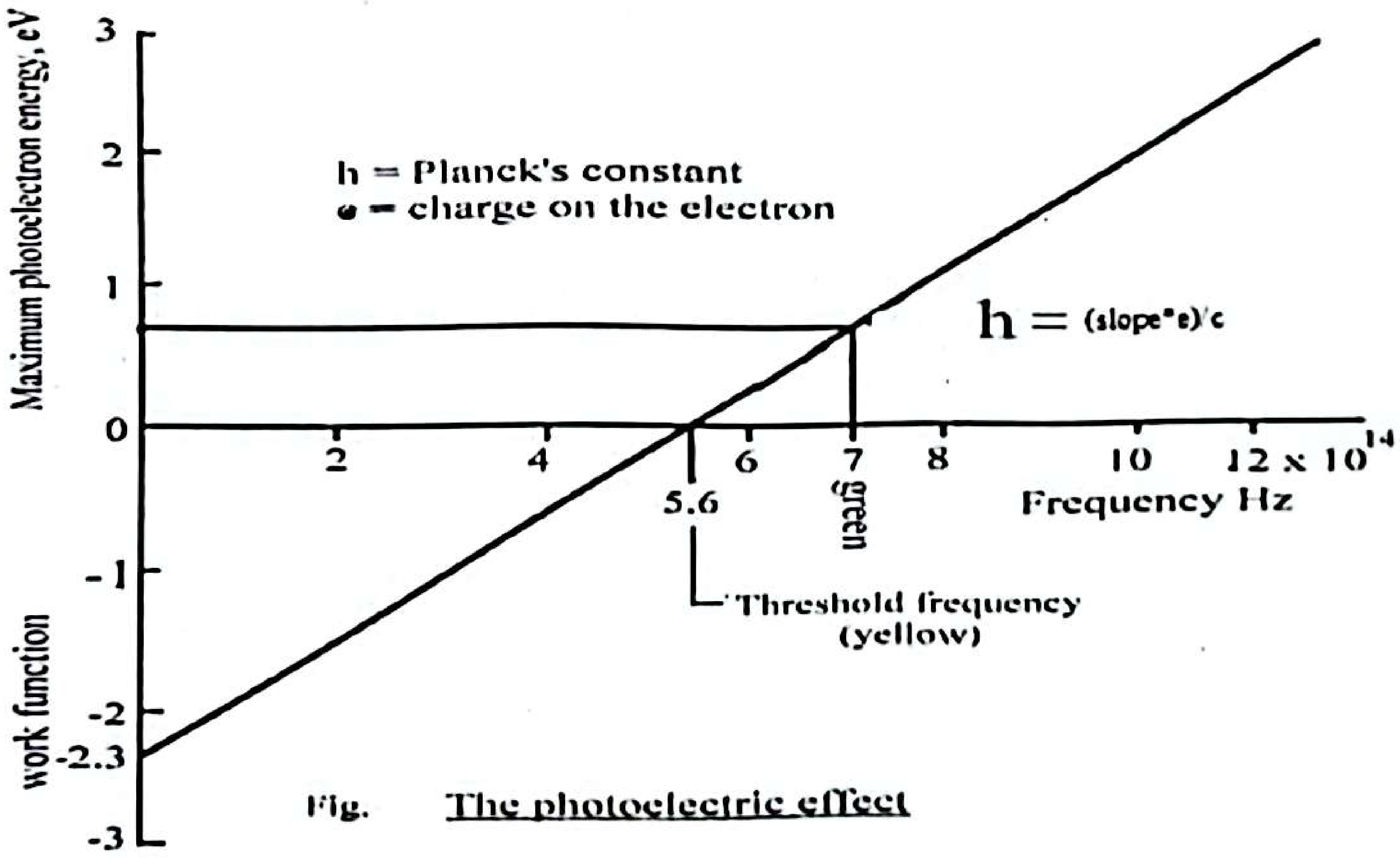


Fig. The photoelectric effect

Step 1:

Convert nm to m.

$$1183.4\text{nm} \times \frac{1m}{10^9 nm} = 1.183 \times 10^{-6}\text{m}.$$

h = (slope × e)/c

Where,

h = Plank's constant (6.626×10^{-34}Js)

c = speed of light (2.998×10^8m/s)

e = 1.602×10^{-19}C

h = (1.183×10^{-6}m × 1.602×10^{-19}C)/ (2.998×10^8m/s)

$h = 6.32 \times 10^{-34}$ Js.

This represents an error of 4.6%. The quality of the results obtained will depend heavily on the monochromatic nature of the light sources used and the care with which stopping voltages are obtained.

Result:

General notes on running experiment:

1. Select tube current on the meter switch to monitor the current through the phototube. Begin by selecting the 0-20 μA range, and as this reduces almost to zero, select the very sensitive 0-200 μA range. If the current exceeds 200 μA, the display will be out of range. Select the higher range again,
2. The light source will be illuminating through the aperture at the rear of the instrument. The light source will become warm, which is normal. However, do not allow the light source to run for very long periods of time unattended or overheating may occur.
3. If the current is over-range, select the higher current range. Leave the meter switch on tube current and increase the backing volts using the knob until the current (electron flow) through the tube reads close to zero microamps. Then select the low range again adjusts voltage to achieve 0.0 nanoamps through the tube.
4. Without distributing anything, select backing volts and observe the exact voltage that is being applied to the phototube in reverse to stop all electrons from reaching the anode. Note the wavelength of the filter used and the backing volts reading.

Oral questions and their Answers:

Q1. What is Photoelectric Effect?

Ans. The photoelectric effect is a phenomenon in physics. The effect is based on the idea that electromagnetic radiation is made of a series of particles called photons. When a photon hits an electron on a metal surface, the electron can be emitted. The emitted electrons are called photoelectrons.

Q2. What do you mean by photoelectric work function?

Ans. The photoelectric work function is the minimum photon energy required to liberate an electron from a substance, in the photoelectric effect. If the photon's energy is greater than the substance's work function, photoelectric emission occurs and the electron is liberated from the surface. The work function is important in the theory of thermionic emission, where thermal fluctuations provide enough energy to "evaporate" electrons out of a hot material (called the 'emitter') into the vacuum.

Q3. What is Planck's law of radiation?

Ans. Planck's law is a formula for the spectral radiance of an object at a given temperature as a function of frequency (L_f) or wavelength (L_λ). It has dimensions of power per solid angle per area per frequency or power per solid angle per area per wavelength.

Q4. What is Photoelectric cell?

Ans. Photoelectric cell, also called Electric Eye, Photocell, or Phototube, an electron tube with a photosensitive cathode that emits electrons when illuminated and an anode for collecting the emitted electrons. Photoelectric cell or photocell is an electronic device which works on the principle of photo-electric effect and converts light energy into electrical energy.

Q5. Which photons have more energy, those in blue light or those in red light?

Ans. Shorter waves vibrate at higher frequencies and have higher energies. Red light has a frequency around 430 terahertz, while blue's frequency is closer to 750 terahertz. Red photons of light carry about 1.8 electron volts (eV) of energy, while each blue photon transmits about 3.1 eV.

Q6. How does the intensity of light affect the photoelectric effect?

Ans. In the photoelectric effect, light incident on the surface of a metal causes electrons to be ejected. The number of electrons (i.e. the electric current) is proportional to the intensity and independent of the frequency of the incident radiation above the threshold value of v0' (no current is observed below v0).

Q7. What does the photoelectric effect show about the properties of light?

Ans. Instead of remaining in a directed beam of light, the light waves spread outward whenever they can. He observed the photoelectric effect in which ultraviolet light forces a surface to release electrons when the light hits. Einstein explained the reaction by defining light as a stream of photons, or energy packets.

Q8. What are the Characteristics of Photoelectric Effect?

Ans. For a given metallic surface, photo-electrons are emitted only when the frequency of incident light is greater than or equal to a certain minimum frequency (v_o) known as the threshold frequency.

Q9. What is stopping potential?

Ans. The stopping potential is defined as the potential necessary to stop any electron (or, in other words, to stop even the electron with the most kinetic energy) from reaching the other side. What happens in photoelectric effect is that, an incident radiation strikes the surface of the metal. When the power supply is set to a low voltage it traps the least energetic electrons, reducing the current through the microammeter. Increasing the voltage drives increasingly more energetic electrons back until finally none of them are able to leave the metal surface and the microammeter reads zero. The potential at which this occurs is called the stopping potential. It is a measure of the maximum kinetic energy of the electrons emitted as a result of the photoelectric effect.

Q10. What is photoconductivity?

An increase in the electrical conductivity of a nonmetallic solid when exposed the electromagnetic radiation. The increase in conductivity is due to the addition of free electrons liberated by collision with photons. The rate at which free electrons are generated and the time they over which remain free determines the amount of the increase.

300 cm = 1 gm

.1 cm

$T = (\overset{1/33}{W} + W')\boxed{g}$ dyens

$= (50+20) \times 980$

$= 68600$

mass [illegible] Unit per length